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Innovation, knowledge bases and clustering in selected industries in the Oslo region

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Preface

This report is the result of six industrial studies performed for the RITTS Oslo project (Regional Innovation Infrastructure and Technology Transfer Systems in the Oslo region). The project was initiated by Oslo and Akershus Business Council in 1998, with financial support from the Commission of the European Union.

Our main task within the Oslo RITTS project has been to map existing interactions between business activities and research and technology environments in the region. More specifically, the objective of our industry studies has been to analyse how technological knowledge creation and diffusion in the region take place, and relate such processes to innovation. The main focus has been on the small and medium-sized enterprises (SMEs) in the region. The industries studied are printing and publishing, food, machinery and equipment, electronics and the electrotechnical industry, and offshore engineering.

An important aim of the project has been to give policy makers insight into the ways innovation performance in the region could be improved. We hope that this report may be helpful in the ongoing work to formulate and implement a more powerful public innovation policy in the region.

The present report is in reality several reports bound into one volume. STEP researchers carried out five industry studies during the summer and autumn of 1999. These are all presented here, as self contained and relatively independent analyses. The different studies were carried through in parallel, and the authors' ambition was to make studies that would be comparable in scope and which would be complementary with respect to choice of industry, but containing much common analytical substance. We introduce this report with a short, synthesizing overview of the main findings of all the industry studies.

The subsequent industry analyses are based on three main sources: First, a range of in-depth interviews with people in the industries (managers, market directors, researchers and operators), in unions and other organisations working in the Oslo region, and from institutions in research and higher education in the area. Second, information has been gathered through the screening of research publications, annual reports, web-sites, etc. Third, information on the industries, on employment, innovation patterns and technological co-operation, etc. has been obtained from a number of data-sets, some of which are maintained by STEP.

Oslo, November 1999

Heidi Wiig Aslesen

Main findings

We present the main findings of the industry studies under three headings:

1. How do firms innovate?
2. What do firms need in order to become more proficient innovators?
3. Suggestions for policy

1. How do firms innovate?

- The Oslo region is quite similar to the Norwegian average with respect to levels of innovativeness in industry. All large firms are innovative, in the sense that they do come up with new or significantly improved products or production processes over a period of 3 years.
- As in the rest of Norway, small firms in general appear to be less innovative: They less frequently come up with new products, they collaborate less, and they have much fewer contacts with academic institutions and research institutes.
- Some small firms operate in relatively stable businesses, and do not experience the same pressures to change as larger firms. Other small firms simply are too busy maintaining their current business to be able to think long-term and innovate as part of their general business strategy. In spite of this, about half of even the smallest firms we have innovation data on, are innovative.
- Innovation statistics may underrate the role of small firms in innovation by ignoring that their activity may be closely related to innovation in other firms. Many small firms that in themselves are not innovative, are in fact part of larger constellations of firms and organisations that taken together represent significant innovators in the regions economy. The high entry and exit rates of small firms also show that the stock of such firms is significant contributing factor to the dynamics of the economy.
- Innovation is often believed to be a separate activity which is additional to the otherwise stable and routine based business operations of firms. Judging from our case studies, this perception is false. Business innovation should rather be seen as an integral part of any conscientious effort to develop a business.
- *Customers, suppliers and other divisions within a larger corporate structure* are the type of partners innovative firms most often collaborate with. The effort to innovate is never a closed technological activity. In order to innovate, a firm has to re-engineer its functional role, that is to say, it must *to some extent* – not always radically – change its relationship to customers and its overall way of doing business, and it must furthermore be able to induce such change in firms and organisations that it co-operates with. Innovation thus involves dealing with those partners that are important for the firm in day to day operations.

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- Innovation is most of the time closely coupled to *technological learning*. This is why R&D collaboration plays such an important role in business innovation. Advanced research in academia and research institutes is potentially an extremely important source of learning for firms. Learning from external milieus is never enough, however. The fundamental competence base developed over time by firm is at the core of successful operations, and the ongoing learning and development inside firms can never be substituted with *infusions* from external competence centres.
 - The matching of complementary competences and the establishment of a pregnant interactive collaboration and learning relationship between internal and external competence holders is one of the key problems in innovation policy. Only when people in the internal and the external milieus find together, and manage to work together constructively, can the real potential of a public knowledge infrastructure be realized.
 - In our studies, we find that collaboration problems are significant. The problems have their roots both in a lack of competence match, in lack of “cultural” match:
 - Business increasingly depends on specialised knowledge. It is often impossible to find the most advanced knowledge relevant for a specific business application in local research institutions. Also, the quality of existing competence varies. A firm requiring the absolute best competence on a specific field in order to build competitiveness, may find that the available Norwegian resources are inferior in quality to resources available abroad.
 - In firms, as well as in research milieus, many competent people are defensive with respect to outsiders, and displays what appears to be over-confidence with respect to the power of their own internal competence base. They find it hard to develop the mutual understanding, the communication and the commitment that is necessary for fruitful collaboration. Such cultural divides are made even more serious by the fact that people in firms and in institutions in research and higher education live in entirely “different worlds”. Their problem context, their motivations and values are diverse, and they operate in institutions and organisations that work differently and are faced with diverging functional requirements.
 - In spite of the obvious problems, we do see that collaboration and interactive learning do take place, and that innovation efforts often are successful. Larger firms are in general better able to establish relationships to public research institutions, and appear to be more successful in deriving positive benefits.
 - The approach to innovation is different in different industries, and changes over time. However, information technology is a key factor in innovation in most industries.
 - A major trend in innovation, which ultimately is closely related to developments in information and communication technology, is internationalisation. Firms increasingly are coupled to an international

network of suppliers and customers. Liberalisation of financial markets also makes ownership across national borders increasingly important.

- Innovation and business development must confront the internationalisation challenge. This is done in several ways, leading to very different needs with respect to strengthening their innovative performance:
 - Many firms continue to build on governance specificities exploiting “home markets”.
 - Some firms attempt a niche technology strategy, where they strive to be internationally competitive in a very narrow market for consumer oriented or professional products.
 - Several firms rely on a symbiosis strategy, where they rely on a strategic alliance with a large corporation, and grow “in the shadow” of this partner.
 - A few firms attempt to compete internationally with their own technology and a broader line of products.
 - Many firms have been assimilated by foreign firms, and play a role as a local subsidiary; either doing a specific set of “global” tasks within the larger corporate matrix, or acting as local producer, sales office or customer service organisation in the local market.

2. What do companies need in order to become more proficient innovators?

The needs we point to are wide, since small companies represent a majority of companies in these industries. On a general level, these are the needs we see as emerging from the studies:

- There is a need for more long-term strategic thinking on innovation activities in SMEs. Innovation activities in SMEs often take place as immediate responses to customers demands, making the innovation process ad-hoc and unsystematic. Links with the scientific community could encourage more long term strategic innovation activity in SMEs. In general, business strategy and business planning are weak areas in most SMEs.
- There is a need to link companies to the research infrastructure in a more systematic way than before. For all industries, we find that few small companies have knowledge of research activities or other activities of relevance at the research institutions in the region.
- Researchers and industry are often living in ‘different worlds’. There is a need to lower barriers between research and industry, particularly to those industries that are more apt to use scientific R&D than others - like the ‘technology sector’.
- Small companies need a more proactive attitude from public authorities and research environments. Many companies are unable to formulate their technological needs, nor to get an overview of which public schemes exist which might fulfil potential needs.

- SMEs need to relate to supply side actors who understand that time is a scarce resource. This means that there is a need for supply side actors to relate quickly to business demands if interaction between the demand side and supply side is to succeed.
- There is a need to overcome mismatches between supply of skilled workers and the demand by industry. Firms have problems in recruiting people with relevant education and work experience in the region. There are mismatches between what firms need and what the educational institutions actually are offering. Many industries express needs for qualified personnel. The graphical industry, for example, is in a period of change where traditional and digital processes are merging, but it is hard to find people combining both these skills. IT is also increasingly important for producers of machinery, and the industry has problems in attracting skilled people.
- To be able to build up personal and technological knowledge, most firms need better access to financial resources, especially in relation to R&D projects. SMEs do have problems in getting risk capital, and often have neither the experience nor the networks that link them up to relevant institutions (such as the Norwegian Industrial and Development Fund).
- There is a need to stimulate technological co-operation as a strategy for small firms, not only between firms but also between firms and less science-based supply organisations in the region, such as regional colleges and vocational training institutions.
- There is a need to develop better information and better understanding of customer demand - and developments of such demand - to ensure industrial innovations can meet demands. The reason is that central parts of the industries have explicit market-related problems. The food industry emphasises for example the need to establish more tight relations to the grocery chain, a task that has increased in difficulty in recent years. The activity of engineering companies is mostly dependent upon the decreasing petroleum activity level in the North Sea, a trend most likely to continue. The graphics industry is very customer-oriented in their innovation activities.
- There is a need to ensure the Oslo region as an attractive and straightforward environment in which to establish a company. Some companies said they had been met by uninterested bureaucrats in questions concerning company localisation or expansion.

3. Suggestions for policy

The Oslo region performs a large share of national research, in a wide range of fields. The research question has been to what degree is this knowledge transferred to firms in the region? Through the needs analysis we found that firms in the region have specific needs that must be covered, and further that there are certain co-ordination problems between the “demand side” and the “supply side”.

- Efforts should be made so that one organisation in the region has the responsibility to generate and distribute full information on what the supply side in the region actually can offer, ‘a one stop shop’. For firms that are searching for

scientific knowledge there is a lack of transparency in the scientific community in the region which makes it hard for firms to approach the scientific communities with their needs.

- This one organisation should be based in one of the regional support institutions that SMEs actually use and are confident with (such as Akershus Bedriftsrådgivning, Næringsetatene, Oslo Business Region, Technological Institute) and should have the responsibility to act as brokers between firms and relevant knowledge providers in the region.
- Even though there is established a broker, the scientific communities should be stimulated to act more proactive towards the business community. Strategic and long-term projects in firms are often neglected as they strive with every-day problems.
- Scientific milieus in the Oslo-region should be made more transparent to firms in the region through (for example) constant updating websites with relevant information on researchers in specific areas, ongoing and forthcoming R&D projects and information on lectures that firms can attend.

When contact between the scientific communities and firms are made, there are still barriers to overcome in relation to the technology transfer process. Active involvement of both parties in the learning process over time is necessary. We have found examples of R&D projects giving firms solution which they see no point in implementing.

- Technology transfer programmes between R&D milieus and firms should have firms' needs for problem solving in focus. Incentives for R&D institutions to foster collaboration with firms can lie in the availability of financial resources to carry out such projects (provided by regional programmes or authorities).
- Institutions that provide funding for industrial R&D projects need to be more 'user friendly'; they need to be made more accessible to firms and have application routines that are less bureaucratic and easier for SMEs to relate to.
- Consider means to give researchers more direct interest in promoting innovation and business development.

SMEs need to take part in technological collaboration, not only with the R&D milieus in the region.

- The explicit formation of networks or meetingplaces to foster contact between firms and the supply side would be an important way of making firms aware of other firms in the region.
- Networks between the educational institutions in the region and manufacturing industry for the purpose of information and formal contact are required. The network meetings should be held in advance of students writing their project work, making it possible to link students to regional industry. Students are a resource that can be better utilised by firms.

- Not all problems find solutions through science-based knowledge. A very large share of firms uses inputs from experience-based knowledge. For this group of firms the regional colleges (through student work and testing possibilities i.e. the engineering faculty), seem to be relevant arenas for competence building. Often SMEs cannot afford employing experienced engineers, so links with educational institutions could be important for innovation activity within firms.

A very important activity for firms to engage in is employees training. Firms are constantly required to relate to new information, new technology and enhanced quality requirements. This leads to strong training needs.

- Employees training courses that are offered in the region must have a reasonable price and need to be short. Institutions offering such courses should also have the ambition, autonomy and financial ability to quickly respond to firms' demands.
- Efforts should be made to make actors in the same sectors in the region come together and discuss their actual need for competence. There should for example be taken initiatives in different branches (i.e. through branch organisations and labour organisations) to map the need for training. There is a need to systematically map competence needs in different sectors that could be presented to the relevant suppliers in the region.

Parts of the regional industry in the Oslo-region are in a period of turbulence and change, i.e. in the off-shore engineering industry many workers are laid-off. There are possibilities for revitalisation:

- Workers facing unemployment may be a source of entrepreneurs. People being laid off could start their own business, and public policy instruments may stimulate them to do so. The FORNY concept could be a model for such a policy instrument, both stimulating laid-off workers to consider start-up as a realistic alternative, as well as supporting those who decide to start their own business with advice, practical help and perhaps capital.

SMEs need help in recruiting laid-off engineers. Helping local SMEs employ experienced engineers could stimulate innovation capability and activity in the firms. In the machinery and equipment industry, for example, there is a great uncovered need for engineer. The policy instrument 'SME competence' may represent a relevant model for such an initiative, in supporting the recruitment of competent persons to work one year with a specific innovation project in an SME.

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Part I: Innovation and knowledge creation in the printing and publishing industry in the Oslo region

By Louise Hvid Jensen

Main findings

Characteristics of the industry

- It is increasingly difficult to categorise printing and publishing as a distinct industry or sector, as production is increasingly integrated with other sectors.
- Printing and publishing is the largest industry in the Oslo region measured by number of employees.
- The industry is dominated by small family-owned firms; one third of employment is in firms with under 10 employees.
- Printing and publishing is locally embedded, as close customer contacts constitute a major element of production.
- Production is in the process of re-directing its core activities, combining elements of both manufacturing and services.
- Printing and publishing is a demand-led industry.
- Printing and publishing companies are traditionally suppliers in the production process.

Knowledge mapping

- It is possible to identify nine areas of activity within graphical production, although they are difficult to define in precise terms.
- Mapping knowledge within the industry shows that there is no longer a clear distinction between tools and products in the industry.
- Considerable changes have occurred in recent years which have reshaped the knowledge base of the industry – jobs that were previously considered separate branches of the industry are today performed by many different people in the course of production.
- A large part of the knowledge base of printing and publishing is tacit, incorporated in the skills of employees, and in the equipment and routines of the individual company. Knowledge in the graphical industries is very specific, and therefore difficult to transfer.

Knowledge acquisition and innovation

- Only 24% of firms in printing and publishing engage in technological innovation. There is almost no tradition for thinking in terms of innovation strategies, and innovation is often the result of a customer request. Selection of new processes or technology is primarily guided by market demand and competition.
- Innovation challenges lie in the need for new ways of organising work flows and combining different skills in the production process.
- Market and organisational innovations, for a huge proportion of companies in the printing and publishing industry, consist of business re-orientation or changes to core activities.
- More than half of innovative firms cite competitors as being valuable sources of information, suggesting that they monitor their competitors and pursue a strategy of imitation rather than creativity.
- Very few companies have contact with universities, higher education institutions or R&D environments, despite the fact that these are the most important knowledge providers to the industry.
- The main means of technology transfer used are the purchasing of equipment, and the recruitment and training of staff.
- The most significant technological trends in the graphical industry relate to the digitalisation of production processes. The demand pattern today is driven by many different forms of communication.
- The competencies required in the industry today do not have traditional roots in printing and publishing, but rather in IT-related activities.
- Few firms engage in formal collaboration, and the links that do exist are informal, based only on occasional communication and activity. The small firms compete in a dense local market; lack of collaboration can be seen as a strategic concern.

Some challenges for the future

- There is a need for training linked to the use of new technology in the sector, and a need to raise sales and marketing competence in order to compete in the international market.
- Competence-building in the printing and publishing industry needs to become more systematic.
- The industry has a need for a more varied and specialised IT knowledge base.
- There is a need to demystify terms such ‘innovation’ and ‘R&D’ within the industry.

Policy suggestions

- Education must be more geared towards the current working practices of the sector, and must focus more on awareness and competent use of the latest IT tools. The greatest need for upgrading is found in IT-related areas, and IT is the most generic form of technology in the industry. There is also a need for a more varied and specialised knowledge base in the industry.
- Support must be given to the development of strategic alliances and collaboration between small companies. It is becoming increasingly important for companies to cover the whole value chain of graphical production, and small companies might benefit from entering into strategic alliances and collaborations with other firms in order to achieve this and be competitive in all areas.
- Policy should support co-operation between R&D institutions and the graphical companies. The R&D environments relevant to the industry should be made more "accessible" to the companies, and the companies should play a direct and active role in pin-pointing relevant R&D areas. This will help to move the industry away from its "demand-pull" orientation towards "supply push".
- Ongoing competence-building must be made more systematic, and conducted on an industry-wide basis, rather than being internal and specific to individual companies.
- Policy-makers should support and participate in international fairs, encouraging contact and interaction with international suppliers.
- There is a need to examine organisational barriers created by operating rules within the printing and publishing industry, for instance the tariff system, as innovation to a large extent involves the combination of skills and the integration of work-flows.

Executive summary

There are implicit reasons for studying the printing and publishing industry in the Oslo region specifically. Firstly, the industry is concentrated in Oslo, and a large customer base for the industry is also found in the region. Secondly, it will help us to show that the industry's connections to the knowledge infrastructure of the region do not play a significant role in creating knowledge and innovation in printing and publishing.

In terms of knowledge-creation indicators, printing and publishing is neither a knowledge-intensive nor a particularly innovative sector. This is partly due to the difficulty of applying the concept of innovation to the sector, and the fact that the knowledge base of the sector is largely informal. The graphical industry is traditionally a craft-based industry, in which production relies on practical problem-solving and close interaction with customers. It consists of small family owned companies serving small local markets. As companies mainly act as one of several disparate suppliers contributing to the final product, the industry is strongly demand-led in terms of developing new knowledge about products or processes. Changes in

products or processes in the industry are generally the result of new methods developed in other sectors such as IT. In the local market, changes often come as a result of customer demand.

For the purposes of our study, printing and publishing should really be separated into *creative* activities and *processing* activities, as innovation challenges differ considerably between these two production areas. Processing activity is primarily driven by logistics, and the need to optimise the efficiency of printing methods. Creative activities are less standardised, the success of a product depending more on adapting to the unique needs of the customer. Production is therefore more oriented towards the integration and development of multimedia technology and serving the customer's needs in all areas of the production.

Significant developments in digitalisation and electronic communications have made it possible for new entrants and even end-users to produce products and perform services that were previously the domain of printing and publishing companies. When this happens, history and culture will decide the sector to which a company belongs, rather than the specific nature of its productive activities (personal comment by Hokstad, 1999). Understanding knowledge creation in the printing and publishing industry in the Oslo region requires awareness of this reshaping of competencies related to the activities of the sector.

As the printing and publishing industry has no tradition of contact or collaboration with R&D environments, competencies in the industry are not shaped by research-based knowledge. Knowledge in the graphical industry is very specific, and therefore difficult to transfer. Competencies are primarily shaped and developed in conjunction with the acquisition of machinery, and with the use of new techniques in solving practical problems or serving customers. Learning-by-doing appears to be the primary method of knowledge creation in the industry. As resources are limited in most small companies in the industry, the strategic development of new products is not on the agenda, and is certainly not pursued systematically. This tends to make innovation an incremental process, best categorised by the term *organisational innovation*. This usually means finding new ways to co-ordinate and combine different skills in the production process.

1. Studying the printing and publishing industry in the Oslo region

Printing and publishing in Norway is geographically concentrated in a few counties, in particular, Oslo, Akershus and Østfold. The industry is made up of a large number of very small independent companies serving small local markets. This naturally explains the concentration of the industry; printing and publishing companies are suppliers in a production process which is closely driven by customers. For this reason the industry is oriented mainly towards local markets. Discussion of the geographical context of industrial development, then, is implicitly significant.

The printing and publishing industry is the largest manufacturing industry in the Oslo-region, representing approximately 38% of all employment in manufacturing in the region. A total of 13,149 people are employed in the industry, the table below gives the distribution of employees into size groups of firms.

Table 1. Distribution employees by size of firms in graphics- industry in the Oslo-region.

<i>Size groups</i>	<i>Number of employees</i>
1	236
2-5	1046
6-9	836
10-19	1413
20-49	1892
50-99	1212
100-249	3398
250-	3116
Total	13149

The table shows that there are a large part of the industry that are working in relatively small firms, 41% of the employees work in firms with less than 50 employees.

The next table gives a view of the industry according to the education level of employees in the industry.

Table 2: Proportions of educational groups, Oslo-region¹. Source: The Employment Register.

	<i>High-school</i>	<i>Univ. I</i>	<i>Univ. II</i>	<i>Univ. III</i>
Printing and Publishing	72 %	16 %	9 %	4 %
All manufacturing	65 %	15 %	12 %	8 %

Printing and publishing companies in Oslo employ a higher proportion of employees with high school as their highest educational qualification than is average in manufacturing in the region (72% vs. 65%). The proportion of employees with a university background is lower than the average for manufacturing. This means that the printing and publishing industry mainly employs people with mid-range or lower educational levels.

The industry has relatively low levels of R&D, particularly when measured in terms of number of researchers employed, but also in terms of direct R&D expenditure and investment compared to the size of the industry, and possibly in terms of R&D intensity as well.

Innovation indicators give the impression that printing and publishing is an industry which is less innovative than other industries. From this perspective it does not appear to be a knowledge-intensive industry. However this does not mean that the knowledge-level of the industry is lower. Our research indicates that a high degree of informal learning takes place in the industry, leading to a high number of self-taught personnel and providing alternative sources for the creation of new knowledge.

One of the main findings of this study, then, is that the statistical indicators typically used to measure knowledge creation and innovation in industry cannot provide an accurate picture of knowledge creation and diffusion in printing and publishing. The study is therefore primarily based on a descriptive analysis of the changes within graphical production, with examples taken from empirical studies of interviews with printing and publishing companies.

Another finding is that printing and publishing is in the midst of very significant changes, meaning that the distinct term "printing and publishing sector" may not even exist in a few years' time. For this reason the sector must be viewed in the context of changes in other sectors, in communications, and in society as a whole.

2. Changing information flows in society – challenges for the industry

Recent years have seen radical changes in the ways that we communicate, and the ways that we use and distribute information. Computer-based information processing and digital storage of information have increased considerably, while the use of paper-based information has declined. This process is a result of standardisation in machines/hardware and software, which have allowed electronic communication to become more efficient and attractive to use. The improved re-use of information, and improved external communication via the internet as opposed to fax or letter, are part

¹ University level I (one or two years), University level II (three or four years), University level III (more than four years)

of this process of digitalisation, changing in the way in which we communicate and produce information.

The great challenge for industries like printing and publishing, which are part of the media and communications sector, is to anticipate future changes in information and communications technology, and the changing needs of their customers. Knut Holmquist from IGM (Institut for Grafiske Media) gives an example of technologically-induced changes in the character of information required by the news market. He says: “newspapers do not compete on news any more, as people get the news faster through other media. Newspapers today are either becoming tabloids or they are “back-ground story” based”.

For five hundred years, the printing and publishing industry has been the main provider of information in society. In the pre-digital world, the communication and distribution of information was quite simple: words were simply printed onto paper for distribution. The industry had a monopolistic position based on highly specialised and relatively advanced technology which demanded large-scale investment and efficient, skilled use (GI, 1995). That monopoly has now been broken by new technologies and easily-accessible information sources, and parallel publishing in different media has increased in recent years. There is, according to Grafisk Inside 1999, currently a 2% annual growth-rate in “normal” (i.e. paper) printing, whereas digital publishing has an annual growth-rate of 22%. The market for new forms of communication and information is increasing, and the future role of printing and publishing is by no means certain. The industry is no longer the natural supplier of future information and communication products.

3. Recent technological developments in the printing and publishing industry

Before exploring knowledge creation in printing and publishing in the Oslo region it is important to review the significant current developments in the industry, particularly since changes in the nature of graphical production are calling into question the term “printing and publishing” as denoting a distinct industry.

Technological changes and new information media such as the internet (and its derivatives, like e-commerce) now provide standardised solutions for sub-sectors like graphics companies, advertising agencies, communication bureaus and numerous IT activities. As a result, printing and publishing is in a process of convergence with other sectors. Printing companies are moving into the pre-press area, while graphic designers are starting up advertising agencies and publishing companies. At the same time, companies traditionally outside the printing and publishing sector are engaging in publishing and related activities, for instance in the case of IT companies designing and producing web-sites. As Terje Overgård, the administrative director of GBL (Grafiske Bedrifters Landsforbund), puts it “it is no longer the question of which market segment or stage of production belongs to the printing and publishing industry that is of interest, but rather the ways in which the competencies linked to

printing and publishing are evolving in order to produce products and services that satisfy customers in the market” (pers. comm. Terje Overgård, 1999)².

3.1 Changes in pre-printing processes

Pre-printing processes have undergone particularly significant technological changes: open standardised computer technology has replaced the old dedicated³ production equipment in the activities of layout, typesetting, reproduction and montage. These activities or phases of production were virtually regarded as separate branches of the industry as recently as 15 years ago (pers. comm. Grjotheim, 1999). Today they are gradually merging together due to the development of information technology. Up until at least the mid-1980s, equipment, tools, techniques and skills used in the individual pre-print activities were highly specialised and non-transferable, for example the writer with their typewriter, the designer with their drawing tools, and the typesetter with their typesetting machine. Transfer of information between the different stages was impossible and at each step the data had to be set up all over again. Making changes was therefore very costly once the process was underway (Kiese, 1994 and GI, 1995). In the future, a company’s life-cycle will increasingly follow the cycles of products and techniques. Flexibility and quick response to changes therefore become central concerns for the industry as technological change progresses (GBL, 1998).

In the mid-1980s, desktop publishing (DTP) revolutionised the structure of the pre-printing process. The breakthrough of DTP came on the back of two other inventions: Apple’s commonly accessible laser printer from 1985, based on a component from Canon, and the already known WYSIWYG⁴ technique (Kiese, 1994, p. 14). Printing and publishing experienced a boom in investment during this period, rising from a per-firm average of 375,000 NOK in 1980 to 832,000 NOK in 1986 before dropping back to the former level in 1989. (Kiese, 1994, p. 92) For the industry as a whole, there has since been a further increase in investment (gross fixed capital formation) from per-firm averages of around 370,000-390,000 NOK in the early 1990s to 521,000 NOK in 1994 (SSB, 1994).

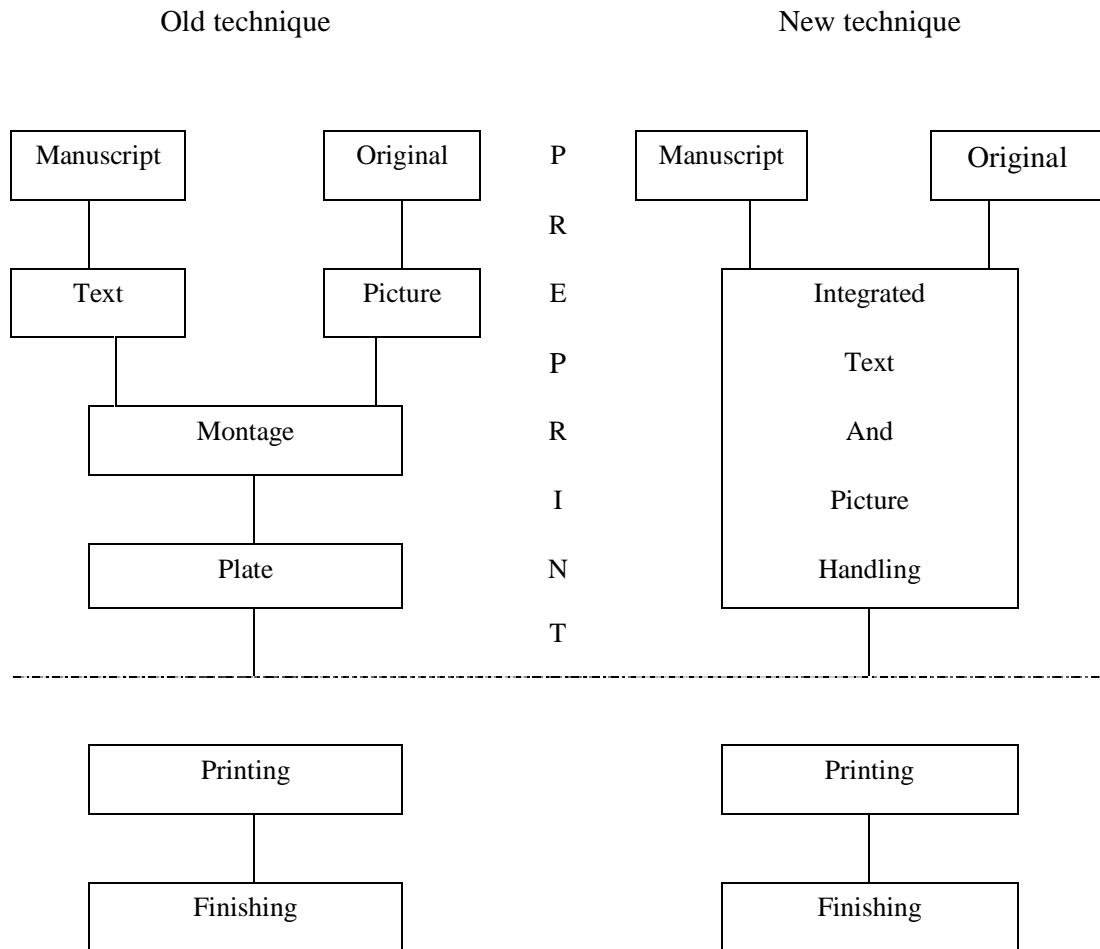
The DTP revolution has made it possible to work simultaneously on text, graphics and pictures within the same integrated unit, thereby merging the formerly disparate pre-printing activities into one activity, for which the same kinds of technology and the same set of skills are used. This is illustrated in figure 1.

² One consequence of this development is that GI (Grafisk Institut) and Grafisk Kompetance Senter have merged and changed their name to IGM Institute for Grafiske Medier – or institute for graphical media.

³ Dedicated: a term used to describe technology which is dedicated to one or a limited range of activities or stages of production, as opposed to open and standardized technology, which can be used for many different operations.

⁴ “What You See Is What You Get” meaning that the screen shows the result you will get on paper.

Figure 1. Changes in pre-printing processes



Source: Kiese, 1994, p. 19

The new technology creates the possibility of using the same equipment throughout the entire process, from writing and picture handling, through layout and montage and finally to printing. The distinction between tool and product is no longer obvious and will probably be even less clear in the future. The text is written and stored on a computer, then transferred electronically to the designer or typesetter before being transferred again electronically to a laser printer or photo compositor. The finished product may not even be printed on paper, but instead sold in an electronic form, such as software, on-line services, or CDs. These trends also signal further convergence of the current printing/publishing, TV/radio and computer-based data handling sectors into an integrated communications or multi-media industry. However, for the moment the majority of the industry's products remain paper based, with electronic products representing only a small proportion (5%-10%, according to GBL and IGM), so these projected developments may have a long time-span.

New so-called computer-to-plate and computer-to-paper (CTP) technologies, together with more advanced laser printers and copy machines, also suggest the possible integration of pre-printing processes with printing activities in the future.

3.2 Changes in printing and finishing

Recent technological development in printing and finishing has consisted mainly of improving existing production techniques and enhancing their efficiency by automating processes using micro-electronics. In addition to automation, electronic administrative systems have been introduced. These systems replace some of the knowledge previously embedded in the minds of offset printers, book binders and other employees, for instance knowledge related to colour management and points regulation (Kiese, 1994, p. 17). Digital printing is becoming more prevalent, meaning that the industry's technology-based monopoly in finishing and printing will disappear over time. This development will contribute further to the noted breaking-down of barriers between traditional printing and publishing activities and the activities of multi-media industries.

3.3 Process integration in printing and publishing

Whereas it was previously made up of a number of sub-processes, the process of graphical production now consists essentially of two main operations, illustrated in Figure 1 as the activities above and below the dotted line. The activities above the line are becoming increasingly integrated with information handling and the editorial and creative processes. At the same time these activities are becoming less dependent physically on plate production and the printing machine. Below the dotted line, the more process-oriented activities are found, activities which are more geared towards multiplication and standardised mass production. Significant technological changes, particularly in recent years, have meant that printing and publishing is in a constant process of re-direction of its core activities. It is increasingly difficult to define and understand which activities can be clearly identified as belonging to the printing and publishing sector of the Oslo region. This has been a particular problem for the established industrial organisations, as they now have to support an industry whose core activities are constantly being integrated with those of other sectors.

In order to understand the printing and publishing industry it is essential to recognise this reshaping of the competencies connected with the core activities of the sector that has occurred. It is only from this historical perspective that it even makes sense to refer to the printing and publishing industry as a separate industry today. Competence in the printing and publishing industry can now be equated more or less to general competence in manufacturing or services.

3.4 Creative and processing activities – service and manufacturing characteristics

The printing and publishing industry is often described as being in a process of transition away from a traditional industrial production structure, developing characteristics and engaging in activities that are more associated with the services sector. This model, developed by the secondary literature and supported by interviews, can be useful for understanding the transitions that are occurring, and the current directions the industry is taking. An example of traditional 'industrial' production in the industry would be a company that produces labels or performs other standard printing tasks. This type of company can remain competitive by reducing costs (per side of paper or label produced) and achieving efficiency in terms

of high speed and low costs. What becomes important for such companies, then, is capacity optimisation, standardisation and low production and delivery costs.

An example of more creative and service-based production activity would be a company that produces magazines, brochures or web-sites. These companies cover the whole value chain of the graphical production process, from writing the content or the information to producing the electronic or paper-based end product. Day-to-day business for these companies more about developing new solutions and competencies based on customer needs; it is often about helping the customer to optimise a communication process. Interactive customer contact and functional networking are central elements to this kind of production, and the competencies required differ considerably from those of a traditional printing company.

These examples could be said to illustrate the fundamental differences between producing physical products and producing or communicating information. At the same time, this categorisation according to the characteristics of the product can be misleading. Is producing a web-page a service or is it industrial production? Or in other words, does a product need to be physically 'hard' in order to be considered an industrial product? This is a good example of the conceptual constraints involved in studying the dynamics of production systems. Instead of thinking of its industrial activity in terms of physical production, IGM speaks of a distinction between *creative* and *processing* activities in the printing and publishing sector (GI, 1995, pp. 20-21). Although this distinction is difficult to illustrate empirically, as many companies perform both creative and processing functions, the approach can be useful for this type of analysis.

Processing activities are illustrated in the first example above, in which economies of scale and low costs are crucial, with *process* innovation therefore dominant. Creative activities relate more to the second example given – production of magazines, brochures or web-sites - in which a production process is rarely reproduced or copied exactly, and projects are often 'new' in some respect. Prices in this creative area are only indirectly related to costs; the value of the product is determined by customer satisfaction. *Product* innovation is therefore likely to be more prevalent in this area, as improvement of the product or service improves its value for customers, thereby creating a better competitive position for the company (GBL, 1993).

4. Innovation and knowledge creation in printing and publishing

This section will present some of the key factors which are important to understanding the innovation capabilities of the printing and publishing industry. We will discuss ways of applying the concept of innovation to printing and publishing, and describe the obstacles to - and success indicators of - the development of new knowledge in the industry.

4.1 Applying the concept of innovation to printing and publishing

In the CIS (Community Innovation Survey for Norway) survey of 1997 the proportion of printing and publishing companies reporting innovative activities was among the lowest of all the industries surveyed. So according to this indicator, the sector appears to innovate very little relative to other industries. This is clearly a

strange result, as radical changes in technology, organisation, products and services have been - and are - taking place in the industry.

Table 3. Proportion of innovative⁵ firms in the Oslo-region and in Norway. Manufacturing industry. Weighted numbers⁶. (N=94, 230). The Norwegian Community Innovation Survey, 1997.

Sub-groups	Nace	Proportions of innovative firms. The Oslo-region. Weighted	Proportions of innovative firms. Norway-Weighted
Publishing and printing	22	24%	28%
Total	15-37	39%	40%

The percentage of firms that claim to be innovative in printing and publishing is 24% in the Oslo-region, this figure being slightly lower than the average for Norway (28%). The data suggests, then, that printing and publishing has a lower proportion of firms taking part in innovation than the average manufacturing industry.

During our interviews, this issue was discussed in detail. Knut Holmquist from IGM said that innovations are quite rare in printing and publishing, if innovation is defined as a process of commercialisation of a new product or process in the market. An example of an innovation in printing and publishing according to this definition would be the introduction of a new font for the screen. Innovations in this sense are not something that every company can develop (personal comment Holmquist, 1999). This perhaps means that this conceptual way of understanding processes of change is misleading and inappropriate for the printing and publishing industry. This is probably partly due to the specific characteristics of the industry, and the institutional structure surrounding the productive activities. Concepts like 'innovation', 'significant change', and 'research and development' are – in this as in studies of other industries - very theoretical. Applying the concept of significant change to printing and publishing companies can make sense if one focuses on understanding what represents significant change for each particular company. This means that for the purposes of this study, innovation is best defined in terms of the development of significant new knowledge and competence within a particular company. As mentioned above, it is also important to distinguish between creative and processing activities within printing and publishing. Continual incremental adjustments and process innovations in printing and finishing techniques, which are generally based on mature technologies, dominate innovation in the processing activities.

⁵ Manufacturing firms were firstly asked whether they, during the period 1995-97, introduced technologically new or improved *products* and/or *processes*. Further, they were asked whether during the period 1995-97 they undertook activity to develop or introduce technologically new or improved products or processes, but which had not produced any results in this period, either because the results were yet to come or because the attempts had failed. If the firms answered positive to any of the three, it was classified as innovative.

⁶ National weights instead of regional weights have been used when looking at the Oslo-region in this report. There is little differences in innovation rates using the different weights (23,58% vs. 24,39%).

4.2 Innovation and creative activities – what is ‘new’ in innovative terms?

The term ‘innovation’ relates to the creation of something that has new value, something that is new on the market (either locally or internationally). In this context, applying the concept of innovation to the creative activities of printing and publishing is problematic. On the creative side of graphical production each product is in some sense unique; it is often developed through close customer contact and therefore adapted to the specific, often unique, needs of the customer. A good example of a product innovation (or significant product-change) described by one of the interviewed companies is the production of a web-site connected to a logistical database system for a bookstore. The company received a request from the customer wanting a web-site design that could be linked to an ordering system. The internet user – the bookstore’s own customer - would then be able to directly order a product for delivery by navigating around the web-site and completing an on-line order form. For the publishing company this required the acquisition of new knowledge in the area of database systems and initiated a significant change in their product development direction.

4.3 Market innovations

There are, on the other hand, a range of creative processes in printing and publishing of which it is difficult to judge the significance. For example, each time a company produces a new design concept that has not been seen before, they have in some sense produced new knowledge, but at the same time this process constitutes one of the basic core capabilities of graphic design.

Aside from the hardware component of innovation, market and organisational innovations are common for a large number of printing and publishing companies as part of this process of business re-orientation. These organisational changes consist mainly of trying to cover as much of the value chain of graphical production as possible in order stay competitive. This has forced many companies to enter into activities and services which did not previously form part of their core activities and competencies. This development can also be categorised as a market innovation, as companies develop new ways of selling their services and products to new segments of the market. One example such change is that of a small graphical company that specialises in producing tourist catalogues: not only do they co-ordinate the entire production process, but they also engage in fund-raising to financially support the catalogue. This means that if a regional council wants a new tourist catalogue produced they may not have to pay anything at all (pers.comm. Mæhlum, 1999). Core capabilities in a company like this are project management and the other organisational aspects of their activities.

5. Innovation and structural characteristics of the industry

Although incremental innovations of products and processes take place continually, the printing and publishing industry is - as noted above - regarded as relatively un-innovative. Most of the technological developments that have had a significant impact on the industry have been developed within other sectors, particularly the computer industry, but also within optics and film. These developments have led not only to new production methods but also to new communications media which are relevant to the printing and publishing industry (Kiese, 1994, p. 9).

5.1 Small units serving small local markets

Part of the reason why concern for strategic product and process development is not prevalent in printing and publishing is due to the structure of the industry. Printing and publishing is dominated by family-owned companies, with a high degree of embedded tradition and routine that constrains their capacity for change. Another significant factor is the size of companies in the industry. As Knut Holmquist from IGM says “a company with 4 or 5 employees does not have time to develop innovations. The companies that innovate are either large, or they are small and just started up on a good idea” (pers. comm. Holmquist, 1999).

5.2 Lack of tradition of strategic thinking – demand-led development

The printing and publishing industry is, furthermore, traditionally a supplier in the production process. Activities are handcraft based, and problem-solving and continual upgrading of routines are part of the general day-to-day practice. As technological change and market demand lead to further integration of work processes, with more of the value chain covered by individual companies, one can expect that more strategic attention will be given to product and process development. However, this re-direction of activities and business orientation is a long-term process. Interviews in the industry indicate that there is virtually no existing tradition of thinking in terms of innovation strategies. When new products or techniques are developed, it is often as a result of a customer request. Technology choices are primarily guided by market demand and competition.

Printing and publishing companies are quite conservative in their outlook, according to Knut Overgård from GBL and others interviewed; they would rather adapt to the environment than create whole new ideas. Knut Overgård says that “they have a supply attitude to their production activities” (pers. comm. Overgård, 1999). This impression was confirmed in interviews with companies, in which innovation processes appeared to be overwhelmingly driven by customers’ demands.

5.3 The role of labour unions

A final factor that is significant in relation to the culture and development of printing and publishing is the strong and long-term role of labour organisations in the industry. As technological change has caused some professions within the industry to lose their position, attitudes towards change have in some cases become rigid. During our survey, a few interviewees gave specific examples of these conflicts. It appears to be in newspaper production in particular that the organisational structure has not adapted to the technology in use. Integration of work-flows also means the integration of skills and competencies; there are significant cultural barriers to this, and changes in institutional structures may take time to catch up with technology.

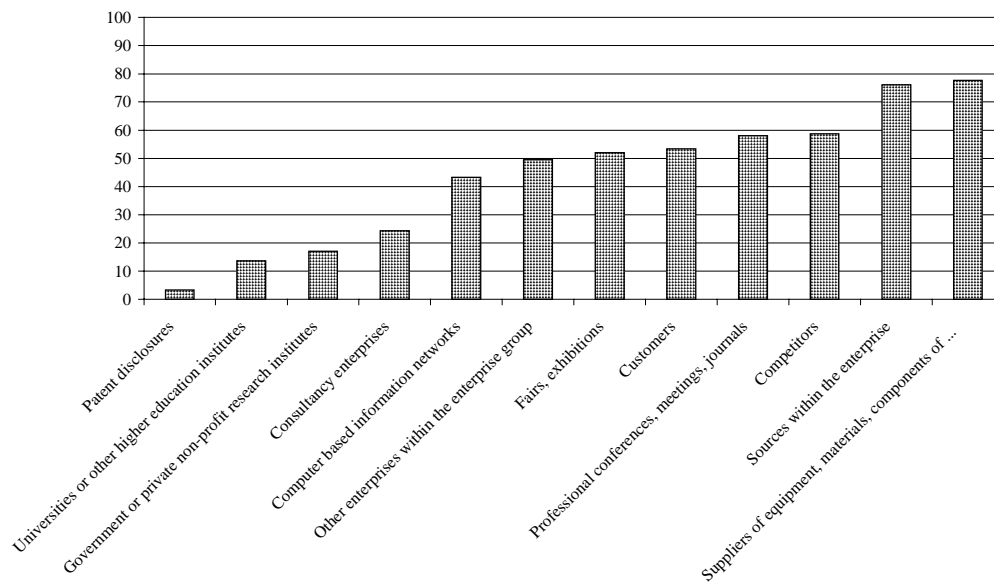
6. Important relationships for innovation in printing and publishing

In GBL’s latest report a selection of companies were asked what they saw as the most important competitive factor for their business. Over 50% of the companies named customer relations as the most important competitive factor. Only 20% of the companies cited price, geographical proximity and technological leadership as being crucial to staying competitive in the market (GBL, 1998, pp. 23). This result is

supported by the impressions given by interviews with companies. As the demand for products and services becomes more diverse and customer-specific, companies are investing more resources in building up their relationships with their customers. Resources and development are therefore mainly concentrated around keeping up with technological changes and providing new products and services via the more or less mature technology base of the company. Technology transfer in production comes first of all from other areas such as services, advertising, administration, and so on. At the same time, companies try to improve the efficiency of production and reduce costs, which can lead to process innovations or distribution innovations (GBL, 1998).

Results from the Norwegian innovation survey correspond with interviews conducted with firms' representatives. Figure 1 below shows the information sources that printing and publishing firms consider the most important.

Figure 2. Proportion of firms that have answered that the following sources are relatively or very important information sources for innovation. Printing and publishing. Innovative firms. Weighted shares. (N=73).



The illustrated answers are from innovative firms, and we can see that close to 80% of these firms consider suppliers of equipment, materials and software to be the most important information source for innovation, closely followed by sources within the enterprise (i.e. employees). More than half of the innovative firms emphasise competitors as valuable information sources, suggesting that competitor observation is common, and that companies will often pursue a strategy of imitation rather than creative innovation. As the chart shows, very few firms have received information valuable for innovation from the scientific community, suggesting that there are few links with this environment.

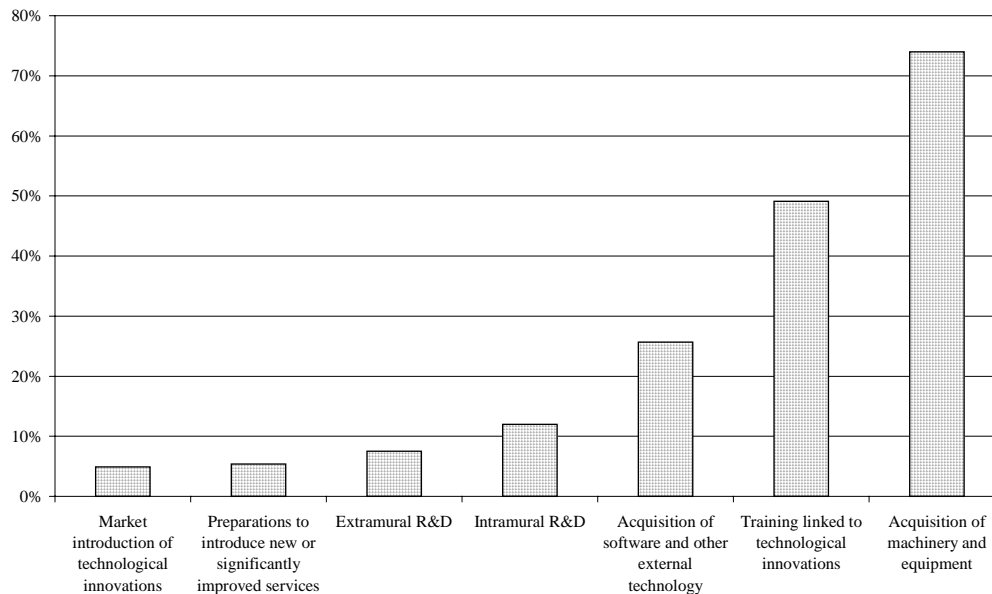
While it is easy to map the potential knowledge providers to the printing and publishing industry, it is another thing altogether to judge the actual value of these

different knowledge suppliers. There seem to be many different ways of obtaining new knowledge in the printing and publishing sector. It is important to acknowledge the fact that printing and publishing is not traditionally oriented towards research and development environments, and companies give few answers when asked what kind of knowledge support they seek in their business environment.

6.1 Innovative activities of the printing and publishing industry

In order to understand further the ways in which this industry innovates or evolves, it is of interest to examine the kinds of innovation activities that the largest numbers of firms in the industry engage in. Figure 2 below shows the pattern of innovation activity for firms in printing and publishing in Norway.

Figure 3. Share of innovative firms that have engaged in different innovation activities in 1997. (N=73).



Close to 75% of the innovative firms have acquired new machinery and equipment, so this appears to be the single most important innovation activity in the industry. Naturally, the training of employees in the use of new machinery therefore becomes an important activity, with half of the innovative firms undertaking this. Very few firms take part in any form of R&D activity.

In spite of the radical technological shifts that the industry has undergone in recent years, and the parallel development of new competencies, general competence-building is not cited as a core element of business development. This is clearly not a systematic process in the majority of the companies interviewed. Most of the companies, particularly the smaller companies, state that competence-building is something for which employees take individual responsibility, often via a process of learning-by-doing or training themselves to use a new technique. Some companies

also mention the wide availability of software programs for self-training, which make it possible for employees to sit down and learn new skills and techniques in front of a computer. Internal competence-building is also common among suppliers.

6.2 Demand pull

The incentives for firms to acquire new equipment are often driven by customers' requirements. The future viability of this very demand-led approach to ongoing company-success that dominates printing and publishing is questioned by some of the interview respondents. As competition from other sectors increases, printing and publishing companies must become more active in selling their competencies to diverse markets. Activities related to anticipating and creating new requirements in the customer base therefore come to the forefront. As one interviewee puts it "competition today is about inventing (or seeing) a missing customer's needs in the market before a competitor does it" (pers. comm. Andvord, 1999). This points towards more active strategic thinking and product innovation, and to the creation of whole new competencies. Management and leadership are crucial elements in the success of this development: "There are a lot of printing and publishing companies in which the owner and leader stands in front of the printing machine – which means that little attention and time is paid to thinking about the long term strategic development of the company, in relation to, for example, competence-building and new market opportunities" (pers. comm. Hokstad, 1999).

6.3 Expanding the knowledge base

Knut Holmquist from IGM furthermore emphasises that a competitive edge in printing and publishing today relies on combining the different skills used in producing the products. In order to attract the interest of readers – this being the main goal of the saturated modern information market - different skills and elements of knowledge need to be combined. Knowledge related to the context of the text, the design of the paper, and the overall form of the product are crucial for communicating the message to the right people. Ten years ago this process involved co-operation between at least four people, while today, a single person might possess all the knowledge required. The competencies overlap, and modern technology makes it much easier to handle different processes that previously relied on hand-craft and experience-based knowledge. The primary challenge is therefore to find innovative ways of organising work-flows, and this kind of development should encompass both the exploitation of technological capability and adaptation to customer requirements.

6.4 From imitation to innovation

The report "Navigating in the future media market" identifies a paradigmatic shift in the orientation of printing and publishing firms in Europe – a shift from imitation to individualism. The report emphasises that creating a unique and compelling vision of a company's future requires more than competitor observation, industry analysis and traditional planning. Creative ideas and innovative strategic thinking become central. This view of a re-orientation within the industry was shared by all of the companies interviewed, although practical and organisational manifestations of this change still appear to be limited.

7. Main features of technology/knowledge-transfer

A large part of the knowledge base of this industry is tacit, embodied either in staff as skills, or in the equipment and routines of the individual company. Knowledge is very context-specific and therefore difficult to transfer. The main means of knowledge-transfer in the industry are the purchasing of equipment, and the recruitment and training of staff. Suppliers of machinery, hardware and software, competitors from related industries, and educational institutions are therefore important knowledge-suppliers to the printing and publishing industry. The next section will examine the network of knowledge suppliers, while this section focuses on the means of transfer.

The predominant means of technology-transfer to printing and publishing companies is the purchase of equipment, as noted above. In a study from 1994, it was revealed that as many as 30% of the printing and publishing companies included in a STEP survey (4/94, p. 59) obtained new technology that way, compared with a 23% average for all industry. Consultancy services - the second most common means of transfer in the printing and publishing industry - were used by only 11% of the companies, compared to an average of 15% for all industry.

Least important for the printing and publishing industry are: contracted-out R&D, and acquisitions of other companies. Surprisingly, recruitment of qualified staff was also rated by relatively few respondents as an important means of adopting technology (4/94, p. 59), although employee qualifications have been cited as being of high importance by industry representatives (Knudsen, 1996). One explanation for these results could be a high level of internal learning in the industry and in individual companies, possibly based on new technology and equipment, since companies report suppliers of equipment followed by sources within the enterprise (STEP, 4/94) to be the most important information sources in terms of innovation.

The transfer of goods to printing and publishing from other industries - i.e. indirect transfer of R&D - is approx. 13 mill. NOK (SINTEF, 1994, p. 21) a year, based on figures from the second half of the 1980s. Around 70% of this was transferred from the business services sector (SINTEF, 1994, p. 21), which had a reasonable R&D performance compared to industry as a whole in terms of proportion of production, of value added, and of gross production value (SINTEF, 1994, pp. 41-42). Another 15% was transferred from the pulp and paper sector (*ibid.*, p. 21), which also shows reasonable R&D levels in terms of proportion of production, but relatively low in terms of proportion of value added and gross production value (*ibid.* pp. 41-42).

The remaining 15% came from the electronic components sector (*ibid.*, p. 21), which is very actively engaged in R&D in terms of proportion of production, value added and gross production value (*ibid.* pp. 41-42). In this respect the electronic components sector is exceeded only by pharmaceuticals, computers and office machinery, and technical/scientific instruments (*ibid.* pp. 41-42). Although it seems odd that the 'computers and office machinery' sector does not figure in the R&D transfer calculations, this may be explained by the time-period of the survey (late 1980s). According to sources from within the industry⁷, the IT industry as a whole is of great importance. The IT industry, although small in volume, receives a considerable

⁷ Grafisk Institutt, Cliché Grafisk, Elanders Norge and the respondents of the research made by Knudsen (1996) and research by Kiese (1994).

amount of public R&D funding (STEP, 4/94), which is then transferred indirectly to the printing and publishing industry.

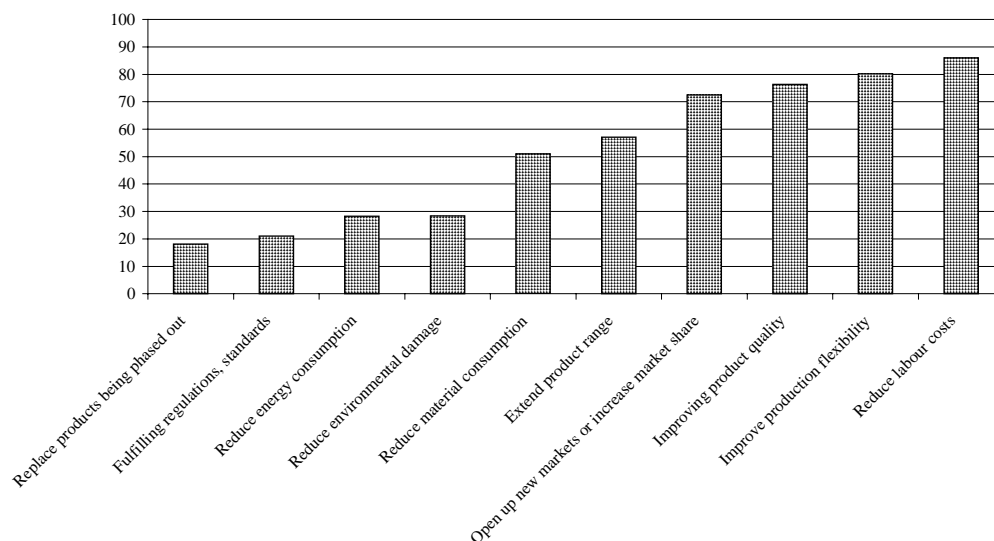
As the printing and publishing industry gradually merges with other industries (IT, TV/film/radio, advertising, etc.) new technology and knowledge is also transferred into the industry via the interchange of personnel, and more generally by competing in new markets with new kinds of partners, competitors and customers. This has expanded knowledge of design and layout, and introduced psychological knowledge from the advertising industry, as well as new techniques and knowledge concerning film editing, electronic communications, and distribution.

8. Are there obstacles to innovation and technological development?

Many of the obstacles to knowledge-creation and technological development have already been addressed in our discussion of the cultural and structural characteristics of the industry. When asked to identify internal barriers for development or innovation companies invariably focus on economic barriers. Aversion to economic risks and lack of economic resources are the factors mentioned, as opposed to, for example, lack of relevant internal competence.

In our innovation survey we asked firms for their reasons for engaging in innovation; the figure below shows the results from innovative firms in printing and publishing in Norway.

Figure 4. Percentages of firms citing the following factors as relatively or very important reasons for engaging in innovation. Printing and publishing. Innovative firms. Weighted shares. (N=73).



More than 80% of the firms see the reduction of production costs as the most important reason for engaging in innovation, followed by the need to improve production flexibility and product quality.

Only one interviewed company mentioned problems with attracting the required competences. All other companies interviewed claimed to have no problems recruiting new employees with the right qualifications. The qualifications and competences required varied a great deal from company to company. Some larger companies mentioned problems with recruiting employees with IT qualifications, although the problem here was essentially an economic one. As one interviewee answered: “we don’t have a tradition for paying the high salaries that employees in IT want – also, the culture and environment that they represent and come from is very different to that in printing and publishing. This is a further hindrance” (pers. comm. Pedersen, 1999).

Some larger companies cite cultural barriers as a reason for keeping the different production activities – design, pre-press, printing, electronic database development - separate in the organisation, arguing that the internal cultural differences are too great to create any synergies between the activities.

8.1 Organisational barriers

This problem may also be partly a result of the so-called tariff agreements that constitute certain operating rules for production in the sector. The tariff system means that an employee must have a profession-based letter of permission or license (fagbrev) to run certain machines and perform certain techniques in the production process. In countries like Sweden and Denmark such rules have been abolished in an attempt to encourage better integration of work-flows and improve cultural integration between different production workers. In the future it might become important to examine the relationship in Norwegian companies between internal learning and development on the one hand, and the tariff system on the other, particularly in comparison to other Scandinavian companies.

As the integration of production and the expansion of individual companies’ products and services proceeds, strategic alliances between companies – particularly the smaller companies – will become more attractive. According to the sector organisations some signs already point in this direction, but the interviews we conducted indicate that only very loose co-operation occurs between companies in printing and publishing. Interviewees pointed to the structure of the industry in accounting for this. As companies are generally small and competing in a dense market, there is a tendency to be highly sensitive to competition. At the same time many companies are family-owned, and ‘emotional capital’ in this type of company can be another difficult obstacle. The few interviewed companies that had entered into strategic alliances seemed to have experienced considerable problems, particularly in overcoming social or cultural barriers.

8.2 Innovation and collaboration

In our innovation study, innovative firms were asked whether they had collaborated with other entities while innovating, and if so, who they had collaborated with. The results showed that as many as 40% of the innovative firms in the Oslo region had engaged in some form of innovation-driven collaboration. The percentage for printing and publishing nationally is lower, at 24%. Looking more closely at the bodies with which firms have collaborated, ‘companies in the same enterprise’ are cited by the highest proportion of innovative firms (58.4%), followed by suppliers of

equipment, material or software (53%). Very few firms have collaborated with the scientific community.

Functional, informal co-corporation appears to be characteristic of the industry, and this conclusion is shared by a thesis studying network co-operation in printing and publishing from 1996. The report concludes that one cannot speak of printing and publishing in Oslo as an “industrial district” or a locally embedded production network. The networks and co-operation that do exist are characterised as being informal, long-term, and falling somewhere between co-operation and competition. This picture was supported by interviews, which showed that most companies had informal arrangements with other companies. None of these relationships seemed to be based on anything other than occasional communication and joint activity; companies might do favours for each other, or make price agreements from time to time. As noted above, this type of relationship between printing and publishing companies is the result of the structural characteristics of the industry; small companies compete in a dense local market, and this creates basic barriers to co-operation, hindering the transfer of core knowledge and the pooling of strategic concerns between companies in the industry.

9. Knowledge mapping

The knowledge-mapping analysis provided in this section is based partly on an empirical framework, which consists of interviews conducted among a random selection of companies within printing and publishing, and with people associated with the sector organisations of the industry. The names of the interviewees and their companies are listed at the end of the paper, and Appendix 1 gives an overview of certain facts about the selection of companies. Companies were selected with the aim of representing a variety in terms of their internal and production characteristics. Based purely on the number of companies interviewed (eleven, plus three people attached to the sector organisations) it is not a representative selection, although, where common threads were detected and the sources supported each other, general conclusions have been drawn based on combinations of the secondary literature and the interviews. The interviews were structured around interviewing guidelines developed specifically for the RITTS project.

9.1 The knowledge base table

In this section, Table 2 gives an overview of the knowledge base of the printing and publishing industry, covering nine different activity areas. The individual technology/knowledge areas and the knowledge and technology providers are discussed in later sections.

The activity categories are based on Knudsen (1996) and Kiese (1994), with some corrections resulting from discussion with the interviewed companies, plus IGM and GBL. The technology/knowledge areas and lists of knowledge suppliers are based on study of industry magazines and material from GBL. The named parties have also assisted in the refinement of the list of technology/knowledge areas, and commented on the knowledge providing institutions.

Table 4. Activities, technology, knowledge, and supplier networks in the Norwegian printing and publishing industry

Activity	Technology/Knowledge area	Technology/knowledge supply
Design/layout	Graphic design, communications (incl. Psychology and pedagogy), informatics, typography Computers, DTP	<u>Hardware:</u> Apple Computer, IBM and other PC-producers <u>Software:</u> Microsoft, Adobe, Quark SHKS (Institutt for grafisk design og illustrasjon) UiO, UiB, UiT, UNIT (informatics, communication) (IGM), new college in Drammen (visual communication)
Typesetting	Typography, informatics, graphic design, communications, paper and ink quality, chemistry Computers, imagesetters, CTP, DTP	Advertising industry, IT-industry <u>Hardware:</u> Apple Computer, IBM and other PC-producers <u>Software:</u> Microsoft, Adobe, Quark IGM HiG (graphics side) UiO, UiB, UiT, UNIT (informatics) Universities in USA and UK (fonts etc.)
Reproduction	Informatics, measurement of contrasts and colours, colour management, paper and ink quality, chemistry IT, computers, repro cameras, scanners, CMS (Colour Management System), DTP	IT-industry <u>Equipment and/or software for transfer of pictures:</u> Apple Computer, Linotype-Hell, Microsoft <u>Scanners:</u> Screen, Crosfield, Scitex, Agfa, Linotype-Hell, Eskofot-Purup, Kodak HiG (graphics side) GI UiO, UiB, UiT, UNIT, NTH (informatics)
Montage	Chemistry, developing, paper and ink quality, informatics, 'utskytning', colour management, optics Computers, imagesetters, Computer-to-plate, test print systems, CMS (Colour Management System), DTP	IT-industry Apple Computer, Microsoft <u>Imagesetters:</u> Harlequin and Adobe (rips), Agfa, Linotype-Hell, Scitex <u>Test print systems:</u> DuPont, Agfa, Fuji, Imation, Axel Brunner <u>CTP:</u> Krause, Kodak, Barco Graphics, Creo, Crosfield, Dainippon Screen, Eskofot, Gerber, Komori, Linotype-Hell, Misomex, Optronics, Polychrome, Agfa, Scitex, DuPont HiG (graphics side) IGM UiO, UiB, UiT, UNIT, NTH (informatics)
Printing or copying	Informatics (network, ctp), engineering, logistics, chemistry, paper and ink quality, printing skills Offset printing machines, digital printing machines (office printers, digital copy machines and actual printing machines), copy machines	IT-industry <u>Printing machines: Offset:</u> Heidelberg, Roland, Miller, Solna, Strachan & Henshaw., Komori, Harris, MAN, Koenig-Bauer, Gos, Rochewell. <u>Digital:</u> Indigo, Xeikon, Agfa, IBM, Xerox, Scitex <u>Copy machines:</u> Rank Xerox, Canon <u>Laser printers:</u> Apple, Digital, Lexmark, Canon, IBM, Hewlett Packard <u>Paper:</u> Stora Papyrus Norge AS, UPM-Kummene AS, Neusiedler <u>Ink:</u> SUN Chemicals, Coates Lorrileux, Casco Nobel, Toyo Inks, Manders HiG (graphics side) IGM Institutet för Medieteknik (Sweden), VTT Information Technology (Finland), FOGRA (Germany), Rochester Inst. of Technology (USA) Polar, Schneider, Wohlenberg, Indigo, Stahl, Heidelberg, Brehner (Fadensiegel), Idab Wamac, Müller Martini, MB Bäuerle and Stahl, Quad/Tech
Binding and finishing	Engineering, logistics, informatics Cutting machines, 'samleslifter', 'falsmaskiner', FCS (finishing control systems, fx. 'i-stik-system' for newspaper sections), process lines	
Electronic products	Design and communication skills (incl. Psychology and pedagogy), film editing, typographics, informatics (programming, databases, networks, etc., VRML,	Apple Computer, MacroMedia, Scala (Norwegian), Microsoft (fonts etc.), Adobe (fonts etc.), Colour Management Consortium, SUN, Netscape, Oracle (server tech.), Skrivevik Data (Java, SUN), RA-Data, Computer Resources.

	HTML/SGML)		IGM
	Computers (work stations and network solutions), DTP, scanners, CD-writers, modems, servers, ISDN	UiO (informatics, and media and communications)	
	Software for drawing, and picture management; digital film editing; sound editing; graphics (incl. 3D); multi-media, integration and transfer tools; homepage production.	UiB (mass communications, information science and informatics)	
		UiT, UNIT (informatics)	
		Norsk Regnesentral	
		SHKS	
			Advertising industry, IT-industry
Publishing and distribution	Jurisprudence, informatics, logistics	UiO (legal informatics, informatics and media and communications)	
	Distribution systems, databases	UiB (mass communications, information science and informatics)	
		HiG (graphics side)	
		IGM	
		UiT, UNIT (informatics)	
Transport	Informatics, logistics		Advertising industry, IT-industry
	Computers, ISDN, internet/intranet, e-mail, modem, server		Apple Computer, IBM, etc.
			Telenor, Telia, TeleDanmark, etc.
			Televerkets forskningsinstitutt
			HiG (graphics side)
			UiO, UiB, UiT, UNIT (informatics)
			IT-industry

(Appendix 2 gives further descriptions of the industry's nine activity categories.)

The activities included in this table are those that are general but also in some way specific to the industry; it excludes activities such as management and administration which are generic in manufacturing and business in general, and it also excludes firm-specific activities such as reproduction of artwork, which require more specific and precise knowledge. Unlike many other industries, printing and publishing is fairly homogeneous in terms of educational structure and production characteristics, and this means that most of the activities of an individual firm will be common to other companies occupied at the same stage of the value chain.

As described in the previous section, the different production activities in printing and publishing are currently in a period of transition, in which activities - particularly the pre-printing activities - are gradually merging together. Typesetting, reproduction and montage, previously separate tasks, can now be viewed as one activity. Despite this development, these do still exist as distinct activities (although they are no longer necessarily linked to a specific function or individual employee) and for this reason they are considered separately in this presentation.

The first six activities in the table describe the production flow from layout through to typesetting, reproduction, montage and finally to printing and finishing. The seventh section describes the group of activities related to the (still relatively small-scale) production of electronic products, while the final two describe activities supporting the graphical production, namely, publishing and distribution, and transportation.

9.2 How representative is the knowledge table of the printing and publishing industry today?

According to the people interviewed, the knowledge mapping table above covers around 90% of the activities in printing and publishing. However, as noted in the previous section, it is increasingly difficult to distinguish the specific activities of the printing and publishing sector. At the same time, the table is very much based on a linear understanding of production, in which we visualise the value chain as a linear flow of physical tasks. This makes some of the main tasks in the map difficult to quantify, as they consist of creating, gathering, organising, selecting, synthesising, transforming and distributing information. For example, the section on activities related to electronic products might easily be extended and placed at a much earlier point in the table. It is important to acknowledge that the processes and activities associated with electronic products are as diverse as those for paper-based products, although it is difficult to depict accurately these different processes and tasks that are involved in the production of electronic publications. Karin Hokstad from GBL emphasises that, unlike in the case of paper-based products such as labels and magazines, systematic knowledge of the different elements of electronic publication has not yet been fully developed. However, it is also important to recognise that electronic publication is not a single, standardised activity, but really consists of many different types of outputs and processes (pers. comm. Hokstad, 1999).

Other activities not included in this mapping are the purely creative tasks of writing the text (journalists and writers) and taking the pictures (photographers), as they are not strictly industrial activities, although writing in particular is becoming more integrated with activities such as layout and typesetting. Interviews conducted with companies in the industry also indicated that activities related to the content of the products are becoming increasingly important. Creating the content of information products requires skills that are not part of the industry's core competences. This represents a great challenge to the industry, but also a potential obstacle to its development, a point to which we will return later in this paper.

9.3 Key activities and their knowledge bases

Traditional graphical production skills such as typography, printing, setting, imposing, contrast measurement, colour separation and matching represent the nucleus of the printing and publishing industry's knowledge base. That is, the knowledge base is dominated by hand-crafts and experience-based work. The skills are highly tacit, and therefore difficult to describe and measure; they need to be shown rather than described, depending as they do on vague, subjective notions such as 'eye', 'feeling', and 'sense of quality'. Learning these skills means learning-by-doing, and the building-up of experience. The basic knowledge and competencies of the people engaged in the pre-press area were mostly obtained under the previous education system, which allowed specialisation in vocational subjects like

Typography, repro-technique, and repro-montage. Such formal education is now devoted to learning specific tools, and attaining a production specialisation around the handling of text, pictures and montage. The new knowledge is linked to the software programs of Quark XPress, Adobe, Illustrator and Photoshop. The ongoing development of these programs is integrating more and more printing and publishing competence and knowledge in order to deliver high quality graphical products (Ruud, 1998). Good graphical qualifications and knowledge are therefore still

required in the production process, although the technology is now more accessible to people without a graphical education. Today, with the introduction of these new techniques, typographers and repro-technicians both work with both pictures and text. This leads to the development of new areas of specialisation, for example in the area of high dissolution of colour pictures, while other skills and tasks become generalised and integrated into other production activities.

New competences are required as activities integrate and new software is developed. Internet publication and parallel publishing require competence and knowledge related to computer systems and network communications. Competence-building in these areas involves expanding employees' basic knowledge of computer technology. This area of knowledge is known as *informatics*: informatics includes programming skills, database administration, network handling, digital film and sound editing, and desktop publishing, as well as basic computer skills and the structuring and codification of information (GI, 1995, p. 41). Electronic publication and commerce in particular require knowledge of database development, and competence in the building and integration of digital workflows. A digital workflow is created the moment data is created by one device and transferred, by whatever means, to another. The magazine *Printing Industries* defines digital workflow in the following way: "the manner in and by which you work arrives within your premises; the process that you employ to interpret, redirect and output the work; and the manner in and by which you offer your work to others" (*Printing Industries*, 1999). This type of knowledge is highly specialised and codified. The competences required do not have roots in the printing and publishing industry traditionally, but rather are found in informatics and in IT-related industries. However, according to interviewees working for companies that are involved in electronic publishing, this knowledge is essential to remaining competitive in the electronic publishing market. If, for example, Siemens wants to publish a new catalogue, a large volume of data must be sorted and processed. The job will consist of structuring documents, pictures and databases in such a way as to make them easily accessible whether Siemens decides to print a catalogue or produce an electronic publication (*Grafisk Inside*, 1999). The focus for companies moving into digital production, then, is not on producing a fixed catalogue (or other product) but on producing and formatting information for use and re-use in different publications and different media. The strategy of producing and delivering one-off fixed products, such as catalogues, will no longer be appropriate in the future. Production of information will, for many publishing activities, be dependant on the media, so there is a need to expand and invest in new areas of knowledge.

Despite the democratisation of the technology used in printing and publishing, "graphic conveyance techniques" and the forming of a visual expression or message are still the core competences in the area of pre-printing (Ruud, 1998). The term "graphic conveyance" implies knowledge of graphic design and its unofficial aesthetic rules concerning layout, combination of fonts, the shapes and sizes of the different parts of the text, as well as general communication skills which are based partly on pedagogical and psychological knowledge, and partly on language skills derived from linguistics and semantics. It also encompasses knowledge about paper and ink quality; awareness of the combined effect of layout, print quality and paper quality is of great importance not only in the actual printing process, but also as background knowledge for activities such as designing and setting.

On the processing side of printing and publishing – where activities relate mainly to printing, finishing and binding – knowledge is more encoded, and the required technical competences more specific. The development of printing and finishing tasks is connected to standardisation and quality control in the production systems. Some knowledge is formal and stored in material media such as manuals, specifications and codes of practice, while other knowledge is more specific and often tacit, connected for instance to the operation of a single printing machine.

As the technology becomes more advanced, work is increasingly focused on the mechanical and electronic systems of the printers. Knut Holmquist from IGM states that the use of trained printers in the graphical industry is decreasing, and that engineers with specific skills in printing are taking over. Printing has essentially become an engineering task. Alongside this development, trained printers are having more direct contact with customers, as a result of product diversification and more individualised product requirements. This means that the qualifications and competences required in the processing area are changing considerably. As Ruud (1998) says, it will be interesting to see whether it is the knowledge and competences of the pre-print specialists or the printers that will be most in demand with the spread of digital printing. The outcome could be crucial for the future of the printing trade. According to the magazine 'Printing Industries', location, time pressure and costs can influence the digital workflow of printing as much as technological competence. Even within the same company, the digital workflow is likely to be different for every job that is undertaken: there will be different methods of transfer, differing file formats, different deadlines, and different people working on the data. Production models therefore change with every new job that the company takes on (Printing Industries, 1999). We would argue that printing is in the process of becoming a creative activity rather than a processing activity.

Disciplines such as chemistry provide important background knowledge for film development, plates production and printing; other knowledge areas like optics and branches of engineering - which concern the still highly specialised machinery and equipment used – are important to printing and finishing. Parallel to technological changes, the content and levels of the knowledge used in printing and publishing are also undergoing significant change.

Logistics is becoming more important to activities such as printing and particularly finishing, as well as distribution.⁸ Increasing focus is being placed on products and markets, and therefore sales and marketing are also becoming important knowledge areas. Among all of the companies interviewed it was clear that timely production and delivery was increasingly important, and for this reason more attention is being paid to the logistics of information and physical products. Competence in the integration and logistics of systems are crucial to the process of optimising and rationalising data flows, and to the re-use of data. Legal knowledge concerning copyright law and intellectual property is another area which is growing in significance due to the development of IT.

It has also become valuable to possess a broader range of knowledge in order to offer consultancy and project management services to those customers who have taken over many printing and publishing tasks themselves. According to interviews and

⁸ Terms like print-on-demand have been introduced, and are used in printing of f.ex. school books as the method makes room for updating and prevents excess production leading to lower unit prices.

surveys conducted by GBL there has been an increase in so-called total-solution-packages, products and services which encompass and perform a variety of activities related to the communication needs of the customer. This type of project-oriented activity requires pedagogical knowledge as well as selling skills (GI, 1995), as the product delivered becomes more than just the output of production; the product also contains the project, the actual process of developing the product in partnership and collaboration with the customer.

Computers, and computer-related technology, are the most generic form of technology in printing and publishing, as they are used in almost all activities. This is not to say, however, that IT is the most important technology/knowledge area for the industry, although it may be that IT is the area with the greatest need for upgrading, and it is certainly the area that attracts most attention. It is important to recognise that the traditional knowledge base remains essential to the industry. In printing and finishing, this traditional knowledge might concern paper quality, ink mixing, and the handling of chemicals, while in pre-printing it concerns page set-up, readability, style, and so forth; these are clearly very important knowledge areas for the industry.

The general impression at IGM is that knowledge in the printing and publishing industry is becoming less specific and more broad and general (GI, 1995, p. 39), encompassing engineering, economics and marketing, pedagogy and psychology, informatics, media, library skills (information structuring and gathering), and design and visual communication, alongside the traditional vocational training (GI, 1995, pp. 55-56).

9.4 Knowledge suppliers and knowledge flows

As highlighted above, suppliers of machinery, hardware and software are also the most important knowledge suppliers to the industry. Although the list of suppliers is long (see Table 2 above) it is far shorter than equivalent lists of knowledge providers for other industries such as food. Printing and publishing companies are relatively homogenous, and the same is true of the knowledge suppliers to the industry. Nevertheless, such a list can never claim to be comprehensive, and there are undoubtedly important suppliers of knowledge that have not been included in this knowledge map. Appendix 3 names the most important suppliers of equipment to the industry. The network of suppliers of equipment and intermediate goods is mainly located abroad, in the US, Germany, Sweden and Finland. Depending on the size and scale of production, printing and publishing companies tend to deal with Norwegian agents of these international companies. Interviews with the companies gave the impression that interaction with suppliers varies a great deal. Some companies - mainly those working on the creative side - have quite formal contacts with the national sales agents of suppliers. Only two companies mentioned direct co-operation in software development or testing with the local agent of a foreign supplier. What does seem to be prevalent, especially for the larger companies that have sufficient resources, is participation in international sales conferences at which the main suppliers to the industry are represented. Companies that are more process-oriented tend to interact more closely with suppliers in finding solutions to problems relating to their specific machinery. Interaction with suppliers in these cases is typically close and long-term, taking the form of communication concerning technology, training, and the exchange of ideas.

9.5 Knowledge diffusion and institutions

Another important network of knowledge exists in the form of ‘human capital’: the minds and hands of employees. Knowledge providers in this context are both the graphics companies themselves, through the large volume of internal learning that takes place (Knudsen, 1996), and their new partners and competitors in the related industries of advertising, TV and radio, film, and IT. Educational institutions also play a role in this network. Although universities, together with NTH, are mentioned in Table 2 as knowledge suppliers, their role is generally of a more indirect character, developing and distributing broader kinds of knowledge which are also relevant to this industry. During interviews only one company claimed to have a direct connection or contact with the regional educational system.

In relation to printing and publishing, the most important educational institutions are Høgskolen i Gjøvik (College of Gjøvik), which is the only institution in Norway offering an engineering specialisation in printing and publishing, and Statens Håndverks- og Kunstindustriskole (SHKS - the State Art & Crafts College), which teaches graphic design and illustration. While Høgskolen i Gjøvik is concerned with graphical production, SHKS is more concerned with the artistic, creative side of graphic design, which will probably become more important to the industry in the future. In a broad sense, the industry also acquires knowledge via personnel educated in general engineering, economics, marketing, pedagogy, informatics, media, library skills, and design and visual communication, areas which are developed and taught at several of the 26 colleges and 4 universities in the country. However, no dedicated printing and publishing or graphical production college exists as they do for example in Denmark and the UK. In Sweden, graphical institutes or departments exist at engineering colleges and universities (GI, 1995). In addition, educational and research institutions, particularly in Denmark⁹ and Sweden¹⁰, but also in the UK¹¹, are used as knowledge sources both by individual Norwegian firms and by IGM.

Finally, Grafisk Institutt – or IGM as it is now called - in Oslo, as the only research institute in the field of printing and publishing in Norway, is a very important part of the knowledge-supply network of the industry. Although most interviewees emphasised the fact that that IGM only functions as an organisation offering courses and up-grading general competence levels, this gives it a special role in the knowledge-supply network as a kind of knowledge centre for the industry.

IGM was founded in 1987 by the trade union Norsk Grafisk Forbund and the two employers’ organisations, Grafiske Bedrifter Landsforeningen and Norske Avisers Landsforening (GI, 1995, p. 15). The areas in which the institute is active are the supervision of technological development, business and sector-related development projects, and training and education, the main focus being on the application of technology in the industry (GI, 1996). This focus means that a high priority is given to knowledge areas related to the use of IT, new electronic products and multimedia.

The R&D areas covered by the institute are company and management development, quality control, printing techniques, environment, trend supervision, new media,

⁹ Den Grafiske Højskole.

¹⁰ Chalmers Tekniska Högskolan, Näringslivshögskola Syd, Kungliga Tekniska Högskolan, Grafiska Institutet and Institutet för Högre Kommunikations- och Reklamutbildning.

¹¹ The London Institute - London College of Printing and Distributive Trades.

visual communication, and IT (GI, 1996). A great variety of qualified personnel are employed at IGM, ranging from typographers, printers, and computer- and graphical engineers, to natural scientists, economists and humanities graduates.

IGM engages in co-operation with domestic bodies such as the media and communication department at Oslo University (UiO), Regnesentralen, and SINTEF. Abroad, IGM co-operates directly with Swedish and Danish institutions, and with European institutions - particularly Scandinavian, Dutch, Irish and British - through EGIN. The main purpose of EGIN is to transfer knowledge between the member countries and to the printing and publishing industry (GI, 1995, pp. 14-15).

9.6 Regional differences and knowledge specialisation

In a broad sense, knowledge flows also differ along the same lines as the previously highlighted distinction between the creative and processing sides of the printing and publishing industry. The processing side of printing and publishing is generally based on more specialised knowledge, its main focus being the development of techniques in order to optimise the quality and efficiency of production. Geographical specialisation, for instance in the case of rotation printing methods in Stavanger, creates knowledge-intensive environments outside the Oslo region, with which some producers find it important maintain links. Rotation printing has increased its competitive position relative to page-based printing, as the rotation techniques are becoming more flexible and easier to control within small-scale production (GBL, 1998). This lowers both production-time and costs. The interviews we conducted seemed to indicate an expansion of rotation printing techniques in the Oslo region. The specialised knowledge and competencies relating to this technique are geographically concentrated around the city of Stavanger. The long-term explanation for this regional specialisation lies partly in the development of label-production for the fishing industry in the region, and it has developed and expanded further as the oil industry has come to dominate the industrial activity of the region. As a result of this geographical specialisation and synergy effect, some of the larger printing and publishing companies in the Oslo region have invested in or bought up rotation printing concerns in Stavanger. According to interviewees, considerable export from Stavanger to Oslo takes place within the industry. Other companies have chosen to use suppliers in Denmark, Sweden and Finland, were they find more favourable prices than are available in the Oslo region.

According to Karin Hokstad from GBL, the fact that no similar specialisation exists in the printing and publishing industry in the Oslo region is probably due to a much more diverse demand pattern. There are too many small printing companies on the corner, serving equally small customers. Globalisation and international orientation mean that printing facilities are more “footloose”, and exports are increasing in the paper-based segments of the market.

9.7 Free information, and new ways of obtaining knowledge

On the creative side of printing and publishing, there is a further important point relating to knowledge-supply and knowledge-transfer. According to the companies interviewed, knowledge and information with respect to electronic products and IT is increasingly obtained via the internet. A characteristic of this type of information is that is not organised by an institution – it is ‘free floating’ information. New

knowledge is obtained through a problem-solving process performed by individuals in front of their computer screens. As one interviewee says: "... if we come across a problem related to, for example, information processing between two different digital systems, we think of somebody to contact that might have had the same problem. This person can be a colleague in Brazil for that matter. The use of IT makes the search for solutions and answers world-wide, and the link with the environment around IT is quite good" (pers. comm. Taubo, 1999).

9.8 Lack of contact with the regional knowledge infrastructure

One reason why regional institutions with knowledge in the area of IT often do not play a part in the knowledge infrastructure of individual companies is that the Norwegian institutions cannot compete in the supply of information in these areas. Knowledge is too specific and embedded in the unique production taking place (see the description above of the characteristics of creative activity in printing and publishing). However, it is important to note that the numbers of printing and publishing companies that are at the forefront in terms of their technological capabilities - and aware of the latest developments on the internet - still seem to be few. As described above, the cultural and institutional environment of most printing and publishing companies is based on customer contact and "making a living on a day-to-day basis". This is reflected by the fact that most of the companies interviewed could not see any obvious benefit in having contact with educational or research institutions.

On the other hand, according to interviewees, personal networks and international contacts are of increasing importance for the transfer of new ideas and new knowledge. International meetings and branch magazines are cited as important aids to obtaining knowledge and news of the industry; they are perhaps even more important today, as more companies are exploring new opportunities presented by the transitions that the industry is undergoing.

9.9 Knowledge diffusion through large companies or customers

Further sources of training and knowledge that are worth mentioning are the large producers in the industry such as Statens Trykning (ST) and large customers that maintain their own internal printing and publishing departments. These environments contain great potential with respect to competence-building.

The GAN group was one of the larger companies interviewed, whose customer base is limited to large organisations such as Statoil and Hydro. These large companies have their own, in-house printing facilities, and the GAN group explain that a great deal of their competence-building occurs in relation to these customers. For instance, it might be that they have employees working part of the time within the customer's organisation. At the same time, co-operation on project development takes place continually. In the case of the GAN group, customer relationships are contract-based, with long term commitments to sub-contracting or in-house activity.

10. Main technological trends in the industry

The latest report from GBL does not anticipate changes using technology that is not already known to the market. Development, it says, will be based on further improving knowledge of existing technology. Technology has to mature in the market, and the main advantages lie in maximising its potential using known techniques (GBL, 1998).

When asked what they regard as the most important current technological trend in the industry, companies point to the digitalisation of production processes – CTP technology. This technology has already been developed, and is in the process of dispersing. A few years ago, changes were driven mainly by radical shifts in technology. Today changes come from both the ongoing development of technological opportunities, and from new demands from customers, these being the result of a more diverse demand pattern related to many different communication forms.

This picture is enhanced by reading the branch magazines collected: they show that software systems that ensure trouble-free digital output constitute the main technological developments of the moment. Integrated management systems and systems that are able to exploit all digital workflows regardless of format, such as NEWAGE, are presented, and the level of technical advance remains high.

11. Policy implications

This section will focus on the knowledge-supply needs of the printing and publishing industry in the Oslo region, and relate this to policy implications. Table 3 presents the arguments and conclusion of this study from a SWOT (Strengths, Weakness, Opportunities and Threats) perspective.

Table 5. SWOT perspective of printing and publishing in the Oslo region

<p style="text-align: center;">Strengths</p> <p>Many companies are used to constant adaptation to technological change and reshaping of their competencies Competencies are both practical and creative, allowing for integration and the creation of new knowledge Close customer/market contact Informal network between companies in the region Some companies seem to have beneficial long term relationships to equipment suppliers.</p>	<p style="text-align: center;">Weakness</p> <p>Demand-led orientation – no tradition for developing own ideas R&D not undertaken systematically Education system is lagging behind developments Lack of economic risk-taking and strategic planning by companies Institutional and cultural barriers between different skilled groups in the production process Lack of time or resources for thinking innovatively; industry consists of small companies serving local customers</p>
<p style="text-align: center;">Opportunities</p> <p>Signals of increase in size of market More integration in production – co-operation between branches Greater international influence and co-operation More integration through customer collaboration Potential for more formal strategic alliances among companies leading to improved market position Expanding the knowledge base and developing new types of integrated skills</p>	<p style="text-align: center;">Threats</p> <p>Printing and publishing competencies less significant as a separate sector (loss of monopoly) Overcapacity in production and declining profit Processing activities move outside the region or even the country due to costs and competition Lack of IT competencies in the region Graphic competencies lose their value in production Companies follow the lifecycles of products/technology Decrease of small firms due to inability to integrate their production and thereby serve customers across the whole production chain Indications of concentration of large companies</p>

A difficulty in making policy suggestions with regard to the printing and publishing industry is that the industry is composed mainly of small companies serving a small local market. It is increasingly difficult to support such industries with policy, as the companies are too small and have too few resources available to be able to think in strategic terms. Finding correct policy instruments that cover the specific knowledge-supply needs of these companies is the main challenge in this relationship. In the case of printing and publishing, policy must be directed towards the very practical obstacles faced by companies – problems that have been clearly identified.

Need to expand the existing knowledge base and competencies of the industry

The future market for printing and publishing seems to include an increased proportion of unique custom-built products, and a further integration of production processes. It will become increasingly difficult to distinguish between products, tools and logistics. A major transition in the sector, and a ‘professionalisation’ of printing and publishing, has occurred in recent years. New products, services and workflows are being developed and integrated into an increasingly diverse range of graphical production processes. Organisational developments are taking place, as companies balance the utilisation of their technological capabilities with adaptation to customer needs. The old model of standardised and separate trades does not fit the new methods of production. New competences are therefore required by this process of transition. The qualifications required in the future, if printing and publishing companies in the Oslo region are to compete in a new open communications sector, will be of a higher level, and more varied and specialised. So **there is a great need for continual development of the industry’s knowledge base.**

There are three types of learning process that are centrally important to knowledge-creation in printing and publishing: Firstly, ‘Learning-by-doing’, which focuses on **internal, technologically oriented specialisation and exploration of existing competences.** Knowledge-building in this area relates particularly to the process of specialisation in obtaining knowledge, and interaction with suppliers. Secondly, ‘Learning by using’, in which both internal and external interaction with users is central. The core process of **building up capabilities depends on a combination of technological and market-based dynamics.** Finally, and perhaps most importantly, ‘Experimental learning’, which leads to the development of new competences. This involves **creating new relationships with customers, suppliers, and regional and international institutions.** This process is geared towards product innovation, organisational innovations and market innovations.

The building-up of competences and new knowledge takes place through different communication channels with a variety of actors, and in order to identify means of supporting these channels it is important to recognise the relevant relationships, both internal and external to the company and its environment. Of crucial importance to this issue is the degree to which the industry itself sees and takes advantage of opportunities to strengthen the relationships mentioned above.

Supporting channels for knowledge-creation

Although most of the companies interviewed claimed to have no problems in attracting the competences they required, they did display a generally sceptical attitude with regard to education levels in printing and publishing, and to the R&D institutes of the region. It can be difficult to provide sufficiently specific training in

schools and colleges, and it was emphasised by interviewees that the most commonly used software programs were not taught properly in today's education system. As the selection of technology is guided by market demand and competition, it is the technology that determines the qualifications of employees rather than vice versa. Technological development means that the printing and publishing industry is in need of competence-building on continual basis – however, this is not currently a systematic process in the industry. Competence-building takes place in companies on an ongoing, unwitting, routine basis, and formalised training or learning is not prioritised. For this reason an important requirement in the future is **to make the process of competence-building more systematic.**

This will mean a demystification of terms like 'innovation' and 'R&D' within the printing and publishing industry. Barriers in the printing and publishing companies' perception of the institutional framework of the Oslo region must be broken down. Relationships between the industry and the institutions of the region need to be created or enhanced, as this link is very poorly developed in some areas at this point. Of the few R&D institutes, most share the specific and often practical focus of the companies' activities, which for many companies means re-educating and re-organising the company in response to changes. **R&D environments relevant to the industry should be made more "accessible" to companies** – companies should play a direct and active role in pinpointing relevant R&D areas. **R&D must have a "supply push" orientation instead rather than "demand-pull".**

As part of this process, more interaction between the users (companies) and the producers (the education system) of human capital is needed. Communication channels must be strengthened between the education system and the printing and publishing industry in the region, matching the supply of competences to the needs of the industry in the future.

Supporting co-operation between companies

Integration of the production process and the emphasis on timely, "just in time" production, means that competitive advantage for printing and publishing companies often lies in covering as much of the product value chain as possible. Small and specialised companies could therefore benefit from entering into formal alliances with other companies whereby they provide for different parts of the customer's requirements. Similar tendencies and strategies have been seen in other parts of Europe.

Abbreviations

Institutions:

AGI - “Aktuel Grafisk Information” (branch magazine)

EGIN - European Graphic/Media Industry Network

GBL - Grafiske Bedrifter, Landsforeningen (branch organisation)

IGM – Institut for Grafisk Media, former GI - Grafisk Institutt (graphical institute)

HiG - Høgskolen i Gjøvik (College of Gjøvik)

NFR - Norsk Forskningsråd (Norwegian research council)

SHKS - Statens Håndverks- og Kunstindustriskole (state arts and crafts college)

SND - Statens Nærings- og Distriktsutviklingsfond (the state business and districts development fund)

UiB - Universtetet i Bergen (university of Bergen)

UiO - Universitetet i Oslo (university of Oslo)

UiT - Universitetet i Tromsø (university of Tromsø)

UNIT - Universitetet i Trondheim (university of Trondheim)

Others:

IT - information technology

DTP - desktop publishing

CTP - computer-to-plate/computer-to-paper

ISDN - integrated services digital network

SGML - standard generalized mark-up language

HTML - hyper text mark-up language

VRML - virtual reality mark-up language (3D language)

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APPENDIX 1

Companies interviewed:

Bergersen - Ørnulf R. Taubo

Beyer Hecos – Øystein Karlsen

Falck Gruppen – Kjell Winge

GAN Grafisk – Bente Wigre

Hansen Grafiske – Gjermund Pedersen

Helli Grafisk – Erik Helli

Milimeterdesign – Paul Amble

NOR Profil – Annar Lille-Mæhlum

Repro Forum – Katrine Andersen

Rich Andvord Grafisk – Richard T. Andvord

Consultant – Håvard Grjotheim (soon in the GAN group)

Grafiske Bedrifters Landsforening – Terje Overgård

Grafiske Bedrifters Landsforening – Karin Hokstad

Institut for Grafiske Media – Knut Holmquist

Other previously gathered sources of information:

Carl Emil

Cliché Grafisk AS

Elanders Norge AS

Further data on the companies interviewed:

Production	Year of establ.	Sales (mill. 1998)	Number of employees	Ownership
Almost whole value chain, specialisation: formularies	1771	170	180	Business concern
Pre-print, printing and finishing, paper converting	1856	130	135	Family owned
Printing – colour print, part of company that covers whole value chain	1904	55	56	Family owned, business concern
Pre-printing and printing – part of bigger that covers whole value chain	1964	63	39	Family owned business concern
Communication bureau Covers almost whole value chain of graphical production	1990	16*	28	Three private owners – partnership
Pre-print, printing, electronic pub., and paper conversion	1924	15	14	Family owned
Multi suppliers of inf. and comm. but little production in-house	1947	15	13	Family owned with one partner
Pre-print only, and project driven production	1989	15	6	Family owned
Pre-print only – in-house production for an advertising agency	1996	4	4	Private owned
Pre-print, web design, and small printing prod.	1982	4	4	Family owned

* Only accounts for part of total sales in 1998.

APPENDIX 2

Knowledge mapping of graphics – a short description of the main activities:

- *Design/layout.* Although traditionally part of other industries and not strictly graphical production, this category is included because the borderline between the graphics-related industries is becoming more blurred, and layout therefore is becoming a larger part of the service offered by printing and publishing companies. Design/layout is a creative process, but is closely linked to the more technical activities of, for example, montage and typesetting.
- *Typesetting* involves preparing the text for print, i.e. the setting of fonts, sizes etc. of the different parts of the text (title, headlines, body matter, etc.) and making up, i.e. placing text and picture blocks in the chosen paper format.
- *Reproduction.* Preparing pictures for print, i.e. scanning the pictures into the computer, identifying colours (colour separation), improving or adjusting the quality of the picture.
- *Montage* is the process of combining text and pictures by transferring them to plate or film: photographing page originals and developing film, arranging the page order/layout, copying the page montage onto an offset plate or film. New IT now makes it possible to skip the traditional plate and film production using CTP¹² technology.
- *Printing or copying.* This is the process of multiplying or reproducing the product. Two main types of printing exist: analogue and digital. Of the analogue kinds, offset printing is the most commonly used, besides this methods such as lithographic, light print and silk print exist, as well as “traditional” copying, i.e. from a paper original. Digital printing is essentially printing on office printers and digital copy machines, i.e. computer-to-copy without a paper original. Included in this category of activity are the activities of paper and ink selection.
- *Binding and finishing.* Binding includes both handcraft and industrial bookbinding, while finishing is mass produced binding of everything else but hardbacks. This category of activity includes folding, stitching, sewing and stapling, gluing, etc.
- *Electronic products.* This category consists of the different activities related to production of mainly CD-ROM and internet-based services. Included here are digital video production, intranets, on-line services, databases, etc. These activities still constitute a minor, although growing, part of the industry, and it is not yet clear whether these are specific printing and publishing activities, which is why they have not been further elaborated in this presentation. At present electronic products are of interest for the printing and publishing industry mainly as complements to paper publication.
- *Publishing and distribution* is the group administrative tasks related to the printing and publishing industry specifically. Publishing could in fact have been treated in more detail, but as the focus of this paper is on production, I have chosen to categorise it as a supporting activity. In this context publishing mainly concerns market related issues and legislation (copyright), while distribution

¹² Computer-to-plate, and eventually computer-to-paper.

includes systems of packing, administration of registers of receivers (mainly in relation to newspapers and magazines) and means of transport.

- *Transport* has been included as an industry-specific activity, although it is often regarded as generic. Transport between companies at the different vertical levels of the production chain, and transport for distribution purposes, has traditionally been time-consuming and costly because of the weight of paper. New IT has now opened up new means of transport via the electronic transfer of information between different parts of the production process, and hence between different companies. New non-paper electronic products are also relevant to this development.

APPENDIX 3

Identification of specific equipment suppliers

The most important supplier to areas in which computers and computer-related knowledge are engaged is undoubtedly Apple Computer¹³. The Mackintosh machine was the first to introduce software applicable to - and seemingly almost specifically designed for - the printing and publishing industry. Since the introduction of Microsoft Windows, PCs are almost as common in the industry, making Microsoft, IBM and other PC producers important suppliers.

Besides these general technologies, more specialised hardware producers include Lynotype-Hell who possess important knowledge of scanners, imagesetters, computer-to-plate technology and transfer of pictures, and Scitex, who are the market leader in digital picture handling. Indigo introduced the term 'digital print' to the Norwegian printing and publishing industry when they presented their new concept of a digital printing machine at a fair in 1993 (GBL, 1995 (a)). Agfa, Kodak, Crosfield, Rank Xerox, Canon and Hewlett Packard are other major suppliers of hardware to the industry.

As for software suppliers, besides Microsoft it is worth mentioning Harlequin, who have played an important role in the development of software for imagesetters and who are conducting research on artificial intelligence (AGI no. 33 p. 39), as well as the other significant software producers Adobe and Quark.

A large proportion of the IT equipment suppliers used are of US origin, as by consequence is the relevant knowledge. Much of the equipment for printing and finishing however is German, while the main suppliers of paper are Finnish (UPM-Kummene AS) and Swedish (Stora Papyrus Norge AS) alongside smaller suppliers like the Austrian company Neusiedler, which won "The pulp and paper Europe award for innovation" in 1996 (AGI no. 33 p. 17).

The dominant supplier of offset printing machines, both in historical terms and in terms of volume, is the German company Heidelberg. Heidelberg machines are probably the most well known and commonly used in printing, and the company also

¹³ Heard at GI: "Suppliers are very important. Apple might be more important than GI!". GI, in co-operation with Apple Computer, has established a multimedia laboratory located at GI in Oslo including six up-to-date computers with internet connectivity, for use in development projects, and for testing, and education and training purposes.

produces equipment for finishing. The Swiss company Müller Martini is another important supplier of both offset printers and binding machines, and Idab Wamac has developed a system for assembling the sections of a newspaper.

Part II: Innovation and technological co-operation in the Oslo region food industry

By Thor Egil Braadland

Main findings

The relevance of the industry

Few people recognise the food industry as a particularly important sector – let alone a dominant sector - in the Norwegian economy. It is a traditional, low-skilled and labour-intensive sector, and the food companies spend seemingly little money on research and development.

However, from the perspective of innovation, there are several factors which make this industry important to the Norwegian economy, and to the Oslo region in particular. Compared to other OECD countries, for example, the Norwegian food industry spend more on R&D than most other countries. Small food companies represent a much higher share of R&D expenditures than national average.

Neither is the industry particularly less innovative than other industries: in a Norwegian all-industry survey from 1997, almost half of the food companies said that they had performed an innovation in the last three years. This figure is close to the national average; higher than we find in Norwegian industries such as textiles, metal goods and graphical industries, but lower than other industries like metals, pulp and paper, and machinery and equipment. According to a European survey, Norwegian food companies introduce radical innovations more often than it's European competitors.

The industry is of interest due to its sheer size: food companies in the Oslo region employ around 7,500 people – equating to approximately 14% of national employment in this industry, and 18% of employment in all manufacturing industries in the Oslo region. Employment in the food industry in the Oslo region is found mainly in beverages and pastry products, representing a total of 4,250 employees, almost 65% of the total food industry employment in the region. Most of the region's employment in the food industry is found in companies with more than 200 employees.

The Oslo region is important because it is here that most of the external knowledge suppliers to the national food industry are located. This applies to food-related knowledge providers, machinery retailers and marketing or market-analysis service providers. This is also where we find the largest food companies, amongst them major head offices in large companies like TINE, Norsk Kjøtt, Maarud, Frionor, Nestlé etc.

Local knowledge suppliers

Food related R&D is produced in and acquired from the Ås complex, the largest supplier of research and technology to food companies in Norway, working in areas such as selection and preparation of raw materials, processing, preservation and storing, packaging, wrapping and coating, hygiene and safety, quality and nutrition, and quality control and documentation. While *Machinery* is often imported from abroad (Germany, Netherlands, Denmark, Japan) many retailers are located in the Oslo region, facilitating personal contact both for training in the use of the machinery, and for repair and maintenance purposes. It is important to acknowledge the significance of major *market research* environments located in the Oslo region, such as BI, AC Nielsen, SIFO, Matforsk, MMI and NILF, providing knowledge on areas such as consumer trends, transport and distribution, trading and marketing, and sales, areas which are of particular and increasing importance to the food industry. There is a broad understanding, in the industry itself, in the Norwegian Research Council, and in an increasing number of studies performed on the food industry, that factors such as marketing and market development, branding, and wrapping/design are becoming crucial to competitiveness in the food industry.

Absorbing knowledge

In terms of technological diffusion and knowledge diffusion, the food industry is in some respects one of the most well-organised production systems in Norway today. The bottom-up vertically integrated system of co-operatives stands as a good example of efficient knowledge diffusion. The system is distinguished by groups of sub-suppliers gathered under commonly-owned umbrella organisations, 'mother' entities with progressive marketing divisions and research laboratories, which actively acquire external knowledge such as research results, market intelligence and technological knowledge. In this respect the Oslo region is important from a national perspective, as many of the food co-operatives' head offices are located in the region, working as knowledge and technology providers, diffusers and co-ordinators for a wide range of producers throughout the country.

Oslo-located food companies also tend to be more knowledge-based and more international in their outlook than other national food companies. They more often engage in technological co-operation with foreign suppliers of machinery and equipment, and perhaps most significantly, they are more likely to co-operate with research institutes. Oslo-based companies also tend to appreciate the importance of fairs, exhibitions and conferences as sources of information on innovation more than companies in the rest of the country.

Employees in the Oslo region are more 'trained for training' than other food processing employees in the rest of Norway. They are, in general, slightly better educated than food employees in the rest of the country. Food companies in the Oslo region more often have employees who are educated in sales, marketing, and accounting, although their proportion of technically educated staff is the same as national average for food companies.

A global trend in the food industry is the 'scientification' of production. In Norway, this manifests itself in over 30 research environments serving food-related areas, both marine products and agrofood products. A disadvantage of this development is

that it moves product development away from the factory floor and into the research department. Hence, employees' practical contact with - and understanding of - the product and the production process is in danger of dissolving. This in turn could lead to decreasing innovative input from the people who have direct relationships to the day-to-day production process.

What do they need?

The interviewed food companies had no clear opinion of what they need in terms of innovation support. Many companies' main complaint was of a narrowed ownership structure in the distribution chains, and the resultant difficulty of bringing new products to market. One company also pointed to a rigid and disinterested attitude from the local authorities with respect to making it attractive for companies to locate in Oslo.

This ignorance of innovation needs can be interpreted in three ways. Firstly, the companies may be well-performing and relatively unconcerned by innovation support needs. Secondly, companies may regard technological and innovation-related tasks as something to be solved by the company itself. Lastly, it may be that they have no articulated or expressed needs; they do not know what they need. According to the research professionals, this third interpretation is the most accurate.

Proactive research environments

So what do they need? According to the company interviews, the small food companies are marked by such typical small company problems as low levels of formal skills within the workforce, high work pressure ("few people get old in this industry", said one interviewee), low technological capability compared with the large companies, and low capital resources. Accordingly, few of these companies will find it fruitful - or even find the time - to participate in general courses undertaken in research environments. The immediate response to this situation should be that policy should be aimed towards making the research environments more proactive towards the food companies. The research environments should listen to the food companies' problems and suggest solutions, or on a more general level, seek to apply and transform existing ideas or research knowledge to the benefit of the companies. One practical measure might be the establishment of one or two full-time research positions whose main function was to visit and advise small companies in the Oslo region on a proactive basis.

Awareness of the importance of market-based knowledge, such as marketing intelligence and trend monitoring, is also crucial in the food processing industry. Small companies often find themselves economically hindered from acquiring such knowledge. One solution could be to stimulate independent companies to join a common organisation whose object would be the discussion of common needs and demands, with particular focus on trend patterns, test panels, interpretations and analysis of social and economic developments with relevance to consumption. The small and independent companies often feel they have little power relative to the four large food distributors in this area. The development of such an organisational body could be one way to increase their negotiating power. Vertical integration with the

increasingly internationalised retail chains would be another long term way of pursuing export business.

Finally, much food-related research has traditionally been aimed at the producers of raw materials. In order to propel innovation and the use of scientific research in the food processing industry, it is important to acknowledge that knowledge means more than just knowledge of raw materials; it also includes technological and market-oriented knowledge. It is important for the industry that the activities of the research institutions reflect this diversity. In other words, the research institutions must move closer to the actual structure of the food-industry in the Oslo region in their research activities.

1. The food industry

Introduction

Few people recognise the food industry as a particularly important sector – let alone a dominant sector - in the Norwegian economy¹⁴. And why should they? It is a traditional, low-skilled¹⁵, labour intensive¹⁶ sector, and the food companies spend on average little money directly on research and development¹⁷. If the food companies innovate at all, the most important changes are often said to be process-based – such as the incorporation of new production equipment and machinery - and the result of developments taking place outside the food industry. In other words, the industry is generally understood to be a technology *user*, playing a somewhat passive, adaptive role in responding to the dominant technological trends.

However, as we shall show, the food processing industry is more complex, more advanced and more innovative than is often claimed. The industry is an important one measured in terms of both regional employment and turnover. The food industry actually represents 25% of all Norwegian manufacturing value added¹⁸, and it produces the fifth highest value added per employee, higher than such industries as electrical and optical instruments, machinery and equipment, and printing and publishing¹⁹. In terms of employment, food represents about 19% of manufacturing employment (Table 1).

Table 1: The Norwegian food industry, main figures, 1996. Source: SSB, ukens statistikk, 35, 1998 (NACE 15).

	Companies	Employment	GDP	Value added
<i>Number/amount</i>	1.730	52.450	96.582 mill NOK	23.816 mill NOK
<i>Share of Norwegian manufacturing industrial activity</i>	16 %	19 %	25 %	21 %

¹⁴ By 'food industry', 'food producing companies' etc. we refer to companies categorised by the National Bureau of Statistics in the 'Food and Beverages' category, NACE 15, i.e. according to the UN standard of industrial classification (Nomenclature générale des Activités économiques dans les Communautés Européennes)

¹⁵ STEP Group (1995), Innovation performance at industry level in Norway; Food, beverages and tobacco, W15-95, Oslo

¹⁶ J. Hauknes (1998), Norwegian Input-Output Clusters and Innovation Patterns, STEP Report R-15-1998, Oslo

¹⁷ STEP Group (1995), *ibid.*

¹⁸ Ukens Statistikk, 35, 1998, SSB

¹⁹ SSB *ibid.*

This paper will attempt to present a broad overview of the dynamics of the food industry in the Oslo region²⁰. More concretely, the core aim of this paper is to analyse the innovation performance of the industry, highlighting possible knowledge gaps and suggesting policy measures which will improve the performance of the system.

Chapter 1 contains a review of the national context of the industry, before looking in more detail at the role of the food companies in the Oslo region. Chapter 2 analyses innovation patterns in the industry. Here we look more closely at innovation performance, innovation directions and patterns of technological co-operation in the industry, at both the national and regional levels. Chapter 3 gives an overview of the industry's knowledge system. We look at three indicators: formal competencies within the industry, the use of R&D in the food industry, and the knowledge base of the industry, with particular focus on the regional distribution of knowledge suppliers. Chapter 4 attempts to map the way in which - and the extent to which - innovation gives the industry a competitive advantage, while Chapter 5 presents the main technological trends in the industry. Chapter 6 contains a summary of the results.

A central theme in this study is the relationship between innovation and knowledge on the one hand, and economic development on the other. Section 0 gives a brief theoretical introduction to this perspective.

Knowledge and innovation in a regional context

This report focuses on innovation and knowledge in the Oslo region food industry. In the 1990s an increasing number of studies from the OECD and the EU have highlighted the role of innovation and knowledge creation in national and regional development. The dominant work which put this relationship on the policy agenda was the OECD publication 'Technology and the Economy - the key relationships' (OECD 1992), marking a shift in the perspective from which economic development was to be understood, and from which policy implications were to be drawn.

One of the central outcomes of this work was that the linear approach to innovation (R&D > invention > product) was discarded, and replaced with a so-called interactive model of innovation. The notion of interactivity stems from the idea that not only R&D, but also factors such as organisational providers of scientific and technological knowledge, marketing, design, testing, and distribution (OECD, *ibid.* p. 25) are important to innovation, and that these factors are interconnected, with multiple and complex feedback loops.

In European economic research, the model of an interactive innovation process has increasingly gained terrain. There is now an awareness among policy-makers that it is not the number of R&D man-years, the number of programmers, the number or sophistication of suppliers of instruments and equipment, or the size of educational institutions *per se* that is important. What is equally important is the way in which these different elements work together to produce products and processes that have market potential. In other words the issue is not just a question of the quantity and quality of elements in the system, it is also a question of how the different elements in the system relate to each other.

²⁰ E.g. the counties Oslo and Akershus

Within the field of innovation studies, one major development has been to give the interactive innovation model an explicit geographical context. Attention has been drawn towards *national systems of innovation*²¹ and *regional systems of innovation*²². When we speak of such localised innovation systems, we mean interactive networks of closely localised industrial units, customers/markets, research institutions, educational institutions, and suppliers and sub-suppliers of, for example, machinery and components. The essential argument of these studies is that innovation is more frequent, and is more apt to be successful, when innovation and learning processes are locally embedded²³.

It is on this theoretical basis that we take a closer look at innovation patterns in the Oslo region's food industry. The central aim of this paper is to map the innovation systems of this regional industry. Central questions to be answered are:

- what is the innovation performance of the food industry?
- how do food companies innovate?
- who are the main local suppliers of knowledge?
- how often do these institutions interact with the regional industry?
- what are the formal competencies within the region's industry?

In a broader sense, the intention of this paper is, by illuminating and answering these questions, to form a platform for policy makers to decide on the extent to which the food innovation system in Oslo is under performing, and whether - and in which areas - there are grounds to intervene. Some policy suggestions are presented in Chapter 6.

The empirical material in this study is collected from three sources:

- i) European and Norwegian statistics and surveys from the food industry.
- ii) Literature on the Norwegian food industry.
- iii) Interviews with managers and employees of food companies in the Oslo region. These interviews, presented as case illustrations, are placed in shaded text boxes throughout the text. The order and locations of these boxes are random. The 'lessons to learn' from the cases are presented on page 109 at the beginning of the document.

²¹ For an overview of concepts and literature, see C. Edquist, *Systems of Innovation Approaches: Their Emergence and Characteristics* in C. Edquist (ed.), *Systems of Innovation: Technologies, Institutions and Organisations*, London, Pinter 1997.

²² Hans-Joachim Braczyk, Philip Cooke and Martin Heidenreich (eds.), *Regional Innovation Systems*, London, UCL Press, 1998

²³ Asheim, Bjørn 1994, *Regionale innovasjonssystem: Teknologipolitikk som regionalpolitikk*, STEP report 1994:18, Asheim, Bjørn and Arne Isaksen 1996, *Location, agglomeration and innovation: Towards regional innovation systems in Norway?* STEP-report 1996:13, Oslo.

Core features of the national food industry

In order to understand the dynamics of the Oslo region food industry, it is important to understand the unique organisational, economical and regional framework within which the industry operates. The food industry is marked by several distinguishing features that separate it from other industrial activities in Norway. Following the summary below, we will give a brief overview of each of these features in turn.

- i) The industry is a large and consumer-oriented process industry.
- ii) Industrial activity is often based on the production of fresh raw materials (with implicitly important links to regulation, production location and transportation).
- iii) The industry has a geographically decentralised production structure.
- iv) Large parts of the industry (e.g. the production of milk, meat, vegetables and poultry) are organised into co-operatives.
- v) The industry is marked by narrow ownership in the distribution system (i.e. few retail chain group owners).
- vi) The industry is based on complex, technologically advanced, and knowledge-based production systems.

Firstly, the food industry is a large and complex industry within the Norwegian economy. We have already presented the size of the industry measured in terms of employment, GDP and value added, and pinpointed the fact that this industry makes up between 1/4 and 1/5 of all Norwegian manufacturing (Table 1). The Norwegian food industry's position in the national economy is more dominant than in any other western country. Measured by share of national manufacturing value added, the Norwegian food industry represented 18% of manufacturing in 1988. The comparable figure for Germany at that time was 10.3 %, for the Netherlands 14.8 %, the UK 12.8 % and France 12.4 %²⁴. Importantly, the industry is market-led, that is, it addresses itself directly to individual consumers, and not to other industries (as do producers of pulp and paper, oil companies, producers of machinery, etc.).

The Norwegian food industry is a de-centralised industry. By this we mean that the industry is a major employer in all (except the southernmost) counties, as shown in Figure 1 and Figure 2. The impact of employment in the food industry is particularly high in the most rural counties, such as Finnmark, Nordland, Troms, Møre og Romsdal, and Sogn og Fjordane (see Figure 2).

The fact that food industry products often contain fresh materials has direct implications for issues such as location of production, regulation and transportation. Product durability, transport technology and regulations (food security, import

²⁴ Wyckoff, A. (1994), *Investment, Innovation and Competitiveness: Sectoral performance within the triad*, EIMS publication no. 2., p. 75.

regulations, etc.) are important issues to consider when discussing localisation, economic development and internationalisation in the industry.

The sub-industrial complexity of the food industry is difficult to overlook. The food industry consists essentially of two broad activities: *marine based food production* – for instance fish, fish products, and fodder - and *agrobased industries*, such as dairy products, mill products, beverages, oils, fruits and meat (See Figure 3 for a full overview). This complexity is also reflected in the industry's knowledge bases; the kinds of technological input the food industry uses to compete and innovate. These knowledge bases involve technological and market knowledge in a variety of areas, such as selection and preparation of raw materials, processing, preservation and storing, packaging, wrapping and coating, hygiene and safety, quality and nutrition, quality control and quality documentation, transport and distribution, and trading, sales and marketing²⁵. Many of these areas are underpinned by relevant national scientific knowledge providers such as Matforsk, Norconserv, SINTEF, and others.

As mentioned above, the food industry really consists of several sub-industries. These sub-industries are in Norway marked by a slightly regionalised division of labour: Fish processing is most important in the northern and north-western area of the country, meat and dairy industries are most important in central and eastern Norway (Hedmark, Oppland, Nord-Trøndelag, Sør-Trøndelag and Østfold), pastry products in the cities of Oslo and Sør-Trøndelag, oils in Østfold, fruits in the larger surrounding area of the capital region (Vestfold, Hedmark, Oppland), whilst the production of beverages is mainly localised to four areas in each part of the country: Oslo/Akershus, Aust-Agder, Troms, and Sør-Trøndelag²⁶.

Another issue which concerns the food industry is the high proportion of agrofood companies belonging to bottom-up controlled co-operative systems. These co-operatives work as common manufacturing, marketing/distribution and product-development organisations for a broad range of local producers of milk, meat, and fruit and vegetables. The level of internal justice in the organisations is high, as is the market share of the producers belonging to the co-operatives. In total, the co-operatives control two thirds of total traded volume in these industries²⁷. The co-operatives are particularly dominant in the production of milk (99.9% market share in 1997), meat (76%), poultry (70-75%) and fruit (49%).

Finally, the industry's distribution system (for instance, grocery stores) is marked by a converging ownership structure. In contrast to the manufacturing industry (which has dominant co-operatives) the stores are mainly controlled top-down by three large owner groups - Hakon Gruppen AS (28% market share in 1998), NorgesGruppen (33%) and Reitan-Gruppen (13%) – and by the membership-owned

²⁵ Knowledge suppliers in the Norwegian Food industry, Braadland (1999), forthcoming

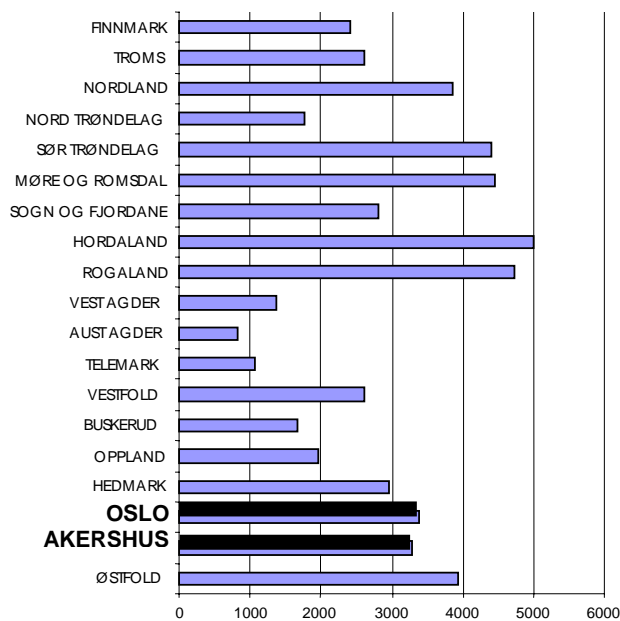
²⁶ A mapping of regional innovation systems concluded that none of these areas are to be considered dominated by the food industry in terms of high employment and a high number of companies at the same time (Isaksen *ibid.*). Statistical source: Employment figures from the SSB employment register, 1996

²⁷ Borch and Stræte; Startegier, strukturer og utviklingstrekk, in O. J. Borch and E. P. Stræte (eds.), 1999, *Matvareindustrien mellom næring og politikk*, Tano Aschehoug, Oslo 1999

Forbrukersamvirket/NKL (25%). Together, these four groups share almost 99% of the total grocery market turnover²⁸.

These, then, are some of the general issues concerning the national food industry. It is important to keep these issues in mind when attempting to understand innovation and knowledge diffusion in the industry. In the following section, we will illustrate the way in which these contingent factors affect innovation amongst the members of the food industry in the Oslo region.

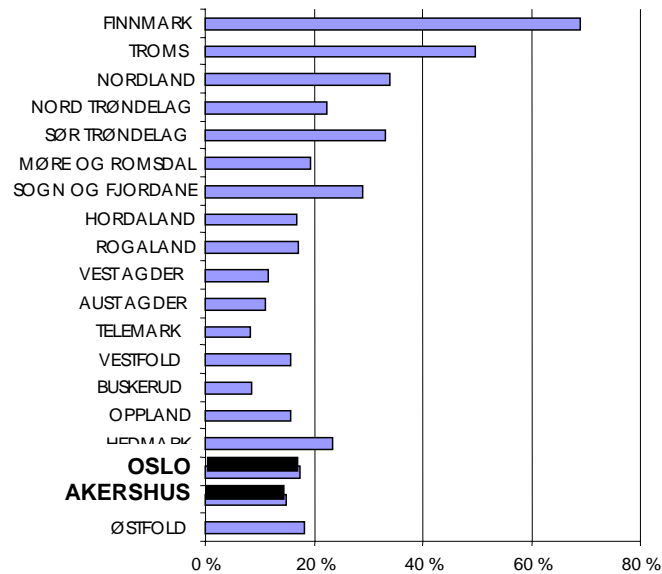
Figure 1: Employment in the Norwegian food industry, 1996 (N=55.113)²⁹. Source: Employment register, 1996, STEP Group / SSB



²⁸ A. Dulsrud; Markedstrender og utvikling i distribusjonsmønsteret, in O. J. Borch and E. P. Stræte (op.cit.)

²⁹ Measured in number of employees living in county and working in the food industry

Figure 2: Food industry employment as share of industrial employment, by county (national average = 21 percent)²⁹. Source: Employment register, 1996, STEP Group / SSB



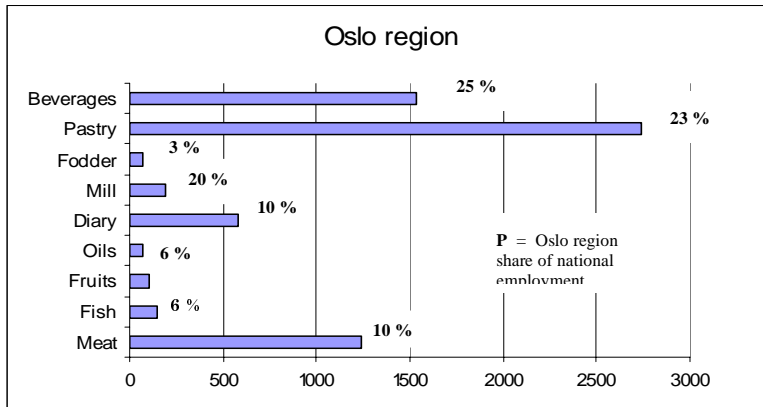
The role of the food industry in the Oslo region

We have described the food industry as an industry marked by a complex knowledge system, and a regionally distributed, to some extent geographically specialised production system. It is in this context that we will look more closely at the food industry in the Oslo region. Food companies in the Oslo region employ around 7,500 people, equating to approximately 14% of national employment in this industry (matching the Oslo region's 14% share of national manufacturing employment). Employment in the food industry represents approximately 18% of all manufacturing employment in the Oslo region, compared to a 19% share on a national level.

As Figure 3 illustrates, employment in the Oslo food industry is mainly confined to two sub-sectors: beverage production, and pastry products³⁰. These employ a total of 4,250 employees - representing almost 65% of the region's food industry employment. There is also significant employment in meat and dairy production: 1,750 people, or 26%. Employment levels for both beverage production and pastry products in the Oslo region represent approximately a quarter of national employment for that sub-sector. (The statistical category "Pastry products" also includes chocolate, biscuits, tea, and other foodstuffs.)

³⁰ The "pastry products" classification also includes food products not elsewhere categorised.

Figure 3: Employment share in the Oslo region food industry, by subclasses, and share of national employment in these classes²⁹. Source: Employment register, 1996, STEP Group / SSB



Which are the dominant food companies in the Oslo region? The National Bureau of Statistics records 183 registered food companies in the region, and Table 2 lists the top fifteen companies and their sub-sectors, ranked by employment. The brewer Ringnes AS is the largest, with 1,485 employees. Freia A/S, producing chocolate products, is the second largest company, with 1,223 employees. Fellesmeieriet AL (milk and milk products), Sætre AS (biscuits), Vinmonopolet AS (alcoholic beverages, and some non-alcoholic beverages) and Fellesslakteriet AL (abattoir) follow, all with more than 200 employees. Together, these companies employ over 5,000 people, representing 80% of all food employment in the Oslo region.

Table 2: Food industry companies located in the Oslo region with more than 100 employees³¹. Source: Employment register, 1996, STEP Group / SSB

Employees	Company	Industry
1485	RINGNES AS ³²	Beverages
1223	FREIA AS ³³	Pastry (others)
411	FELLESMEIERIET A/L	Dairy
334	SÆTRE AS	Pastry (others)
219	VINMONOPOLET AS ³⁴	Beverages
215	FELLESLAKTERIET A/L	Meat
183	FINSBRÅTEN AS	Meat
181	BAKERS ØKERN AS	Pastry
143	NORSK ISKREM BA	Dairy
120	SKOGA BRØD AS	Pastry
115	FURUSETH SLAKTERI AS	Meat
113	SAMSON W B AS	Pastry
111	NESTLE NORGE AS	Fish
106	IDUN INDUSTRI AS	Pastry
105	REGAL MØLLE AS	Mill
SUM: 5064	(equals 80% of all Oslo food industry employment)	

If we look more closely at the employment structure, we find a disproportionate number of people working in large companies. More than 50% of all employees work in companies employing 200 or more people. The comparable figure for all of Norwegian manufacturing is just one third of all employees working for large (over 200 employees) companies (Table 3).

This also means that there are relatively few people working for small food companies in Oslo. Only 18% of food employees located in Oslo work in companies with less than 50 employees. For all Norwegian manufacturing companies, the corresponding share is twice as high: 36%.

Table 3: Employment distribution in Oslo region food companies compared to all manufacturing in Norway, by employment relative to company size. Source: Employment register, 1996, STEP Group / SSB

	1-49	50-199	200+
Oslo region food companies	18 %	30 %	52 %
Norway (manufacturing)	36 %	31 %	33 %

³¹ Measured in number of persons working in food companies located in Oslo or Akershus. Employment in large enterprises with regional distribution of labour (for example HQ in Oslo region and production facilities in other parts of Norway registered as separate companies) is counted in number of employees working in Oslo and Akershus.

³² Second largest manufacturing company in the Oslo region

³³ Fifth largest manufacturing company in the Oslo region

³⁴ The data are from 1996. The former state-owned brewery, wine agency and distribution/retail network Vinmonopolet is now split into two; one import/production and distribution company (Arcus AS) and a retail chain (Vinmonopolet). The import/production division of Arcus A/S (Arcus Produkter AS) had in 1999 about 250 employees, the same in the distribution division (Arcus distribusjon AS).

The reason may be found in the geographical distribution of the food industry in Norway. There seems to be a solid pattern of how large companies locate their different internal activities. For large companies like Maarud, Mills, Frionor, Nestlé/Findus, TINE and Norsk Kjøtt, the overall pattern is that production is regionally localised, while market divisions, research and head offices are located in the Oslo region. Maarud, producing potato chips, tacos and pommes frites, has its production facilities at Disenå between Skarnes and Årnes, while sales and marketing is located at Rodeløkka in Oslo. Nestlé has a market and sales office at Billingstad in Asker, with Findus factory at Hammerfest in Finnmark. TINE Norske Meierier is owned by several dairies located in different regions of the country, but with sales, marketing and research division in Oslo. Frionor has a marketing and research division in Oslo and a production location in Trondheim. Mills has head office in Oslo, with production in Fredrikstad, Drammen, Lillehammer, Trondheim, Finneidfjord in addition to Oslo.

Summary

In this chapter we have presented the food industry of the Oslo region within the context of the surrounding national framework. The food industry is distinguished as a large and consumer-led process industry, with a decentralised production structure. It has complex, technologically advanced and knowledge-based production systems, a geographical division of production, large sub-sectors organised into co-operatives, and a narrow ownership structure in its distribution system.

We have initially looked at two key features of the Oslo region's food processing companies: their size, and their division by sub-sector. Food companies are, on average, larger than other manufacturing companies. The fifteen largest companies represent 80% of the food industry's total employment in this region, and less than one in five employees works in a company employing under 50 employees.

In terms of sub-sectors, 65% of the region's food employment is found in either beverage production or the production pastry/miscellaneous products (including chocolate, tea, and biscuits). Oslo region employment in the production of beverages represents $\frac{1}{4}$ of national employment in the sub-sector. The same is true of the region's employment in pastry/miscellaneous products.

In the next chapter we will take a closer look at the dynamics of the food industry. We will look primarily at innovation patterns in food processing companies, with focus on the frequency with which food companies innovate, the ways in which they innovate, and the sources that are important to innovation.

2. Innovation performance in the industry

Introduction

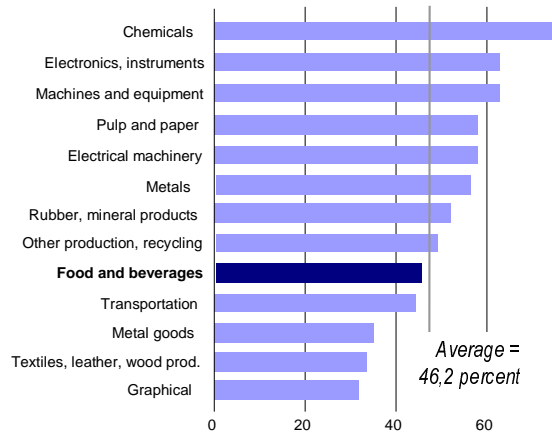
This chapter will examine innovation performance in the food industry. By innovation we usually mean the development and production of new products, or the production of an existing product in a new and better way (either technologically or organisationally). Firstly we will look simply at the rate of innovation in the industry; how often food companies innovate compared to those in other industries. We will then look more closely at the ways in which food companies innovate, the core questions being: what direction does innovation take, and how can such activities be undertaken? To illustrate these topics, we will use information from statistical sources and interviews conducted within the Oslo region food industry. One basic method is to look at the main sources of innovation, and in this context we will examine trends in the use of research and development (R&D). However, for the food industry, R&D is only one part of a very complex knowledge structure, and we will also investigate indicators from other knowledge sources. With this aim, we will examine any patterns of technological co-operation that can be traced in the industry, with emphasis on the ways in which the food processing industry differs from other industries.

One of the main conclusions of this chapter is that the food industry does not innovate any less frequently than is common in Norwegian industry. We also quantify the role of research and development in the industry, along with other important innovation sources such as new machinery/equipment, and market research. Finally, we examine technological co-operation, and the differences in this area between Oslo-based food processing companies and provincial food companies. One major difference is the way in which Oslo-based companies collaborate internationally in developing new technological products or processes.

Proportion of innovative firms

In a Norwegian all-industry survey from 1997, 45% of food companies claimed to have performed an innovation in the last three years (Figure 4). The average proportion of innovative companies for Norway as a whole was 46.2%. The food industry is therefore, on average, no more or less innovative than other Norwegian industries. The food industry's percentage of innovators is higher than that for Norwegian industries such as textiles, metal goods, graphical industries (for which 35% claimed to have performed innovations) and production of transport equipment (44%), but lower than we find in industries such as metals, pulp and paper, and machines and equipment (roughly 60%).

Figure 4: Norwegian industries and proportion of companies reporting innovative activities, source: Community Innovation Survey Norway, 1997, STEP Group / SSB, N=1972³⁵.



How do food companies innovate?

Towards a new understanding of innovation in food companies

It is common to describe the food industry as a *technologically dependent* industry. By this we mean that the industry, when innovating, performs process innovations through buying and implementing new knowledge, machinery, and equipment developed by its suppliers³⁶. A large volume of international literature has defended this approach, arguing that innovations in food companies are mainly process-oriented, and therefore generally the result of creative processes taking place outside the industry. This dependency perspective is related to the view that the power of industrial development lies beyond the control of the food industry.

This perspective represents an influential interpretation of innovation in the industry. According to a European study on innovation in food companies (including Norwegian companies), the food industry is a predominant user of externally acquired knowledge: *“The considerable size of this industry implies that many of its firms will be especially responsible for making use of innovations developed in other technologically more advanced industries (e.g. biotechnology)... Despite its ‘low-tech’ reputation, a striking observation from the study is the radical nature of both product and process innovation in the industry over the past twenty years or so.*

³⁵ Share of companies in sample reporting innovation. In this sample, large firms are better represented than small firms. Since the probability of being innovative increases with firm size, the actual /weighted innovation share is a little lower for all industries than presented in the figure. Average for all industries, weighted share is appr. 40%, in the individual industries the share is between 3 – 10% less than presented in the figure. For the food industry, the difference is about minus five percent.

³⁶ Pavitt, K: *Sectoral patterns of technical change: towards a taxonomy and theory*, p. 343 - 373, Research Policy 13, 1984

There is a high degree of dependence on those developments in high-tech areas, like information technology, biotechnology and advanced materials."³⁷.

However, the technological dependence of the industry is only one part of the story. Increasingly - according to a large European survey on innovation - the main driving force of innovation in the food industry comes not from suppliers of machinery, but from market conditions: customer needs and consumer trends influence heavily the product portfolio of the food industry, and thereby the direction of innovation. This is illustrated by the replies of European companies when asked what they regarded as the most important external stimulant of innovation: 'market conditions' was the dominant reply, over 'suppliers of machinery'. Companies report that market developments are among the most important influences on their business activities. In the words of the EU report: "*(T)he 'supplier-dominated' label is no longer adequate. Firms in this industry assess product innovation as being as important as process innovations in their goal of innovation, and see market developments as more important than either. Clients and customers - not suppliers - are regarded as the most important single source of information leading to innovation.*"

In other words, we must understand the industry not only as a passive *user* of technology, but also as a dynamic, responsive and conscious product and process *developer*. Increasingly, the food industry pays great attention to input signals from market patterns, changes in consumption, new sociological and economical settings, and other market signals. This leads us to conclude that the food industry is *increasingly demand-driven*, and that knowledge about markets is a central element in the inter-active innovation model of the food industry.

R&D as a knowledge input

We have seen that the process of knowledge input to the food industry is complex; it is often based on the implementation of advanced machinery and equipment, but also increasingly based on the monitoring of market trends, consumer desires, competitors' products, and so forth. What then is the role of R&D in the industry?

The Norwegian food industry's share of all manufacturing R&D has, since the 1970s, fluctuated between 5% and 8%, low figures compared to its 20% shares of manufacturing employment and value added. However, there are alternate ways of analysing these apparently low R&D levels. If, for example, we look at R&D expenditures as share of industrial gross value of production, we see that Norwegian food companies spend more on R&D than food companies in France, Denmark and Great Britain. Norwegian food processing companies (including tobacco) spend on average 1.4% of GDP on R&D. The figure shows in other words that the R&D level in Norwegian food processing companies is higher than in most other OECD countries.

³⁷ Jesper Lindgaard Christensen, Ruth Rama and Nick von Tunzelmann, *Innovation in the European Food Products and Beverages Industry*, European Innovation Monitoring System Publication 35, IKE Group, Aalborg University (DK), 1996. The report can be ordered from the EIMS homepages of EU Commission's Innovation Programme (<http://www.cordis.lu/eims/src/stud-3.htm>).

Table 4: R&D expenditures as share of industrial gross value of production, selected industries and OECD countries, 1993. Source: OECD ANBERD database

Industry	Country	Denmark	Finland	France	Netherlands	Norway	Great Britain	Sweden	USA
Food and beverages		1.2	2.1	1	2.6	1.4	1	1.5	1.1
Textiles		0.4	1.1	0.8	0.4	1.6	0.7	1.3	0.5
Wood and furniture		0.2	0.4	0.7	0.1	0.6	0.2	0.5	0.5
Pulp and paper, graphical		0.2	1.6	0.3	0.1	1.3	0.2	2.1	1.3
Chemicals		9.7	8.9	8	7.6	10.5	12.2	15.6	10.5
Metals		3.9	2.6	3.5	3.8	7.2	1.6	3.8	1.6
Mechanical products		5.8	9.1	12.5	7.4	8.1	9	19.6	13.7
Others		15.1	3.8	1	0	0.8	1.7	1.4	3.8
All manufacturing industries		4.2	5	6.9	4.9	5.1	5.9	11.2	8.1

An obvious conclusion here is that any interpretation of R&D expenditure levels is dependent on the way in which we choose to measure and compare it. Another point to be noted is that food-related R&D, measured as a share of total Norwegian manufacturing R&D, is slowly increasing. With the exception of 1996 and 1997, the food industry's share of R&D has been higher than ever before during the 1990s; around 8% of all manufacturing R&D. One reason for this is that manufacturing R&D in general has been increasing at a slower rate than in previous decades. But food R&D also increased in the late 1980s and mid 1990s, and one direct reason for this increase was the special governmental funding grant to Norwegian process industry in 1993-1994, of approximately NOK1bn.

It is important to bear in mind that food producers may have a higher capacity for technological absorption than producers in other industries. Much R&D and collaboration with the agrobased research environments in Ås is financed through co-operatives such as TINE and Norsk Kjøtt (source: Roger Abrahamsen, NHL), and these large co-operatives - being vertically integrated production systems - are entities in which knowledge can be spread more easily among suppliers than in sectors comprising more individualistic actors.

Significantly, most of these co-operatives' headquarters are located in Oslo. Hence it is plausible that the food industry in the Oslo region functions as a strong and centralised bridging entity to the rest of the Norwegian food companies, for the dissemination of knowledge on the use of R&D, product and process development, technical and market intelligence, and quality control. This structure might also be beneficial in areas such as marketing, distribution and negotiating power in relation to the retail chains.

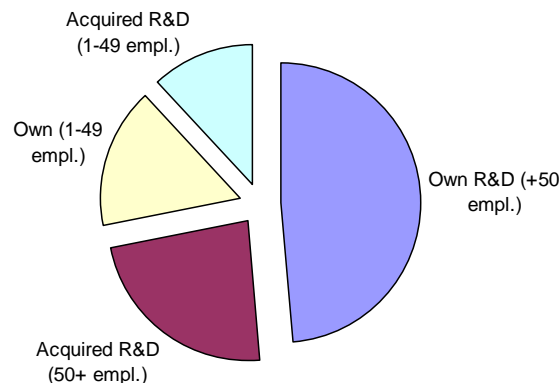
R&D financed by SMEs

Most of the money spent on R&D by food companies stem from large companies. Three quarters of total R&D expenditures in the industry is financed by companies with 50 employees or more. Compared to the national average of 93 percent, this is still a very low share. Small food companies represent in other words a much higher share of industry R&D expenditures than what we find in most other industries.

The major bulk of research is performed inhouse (Figure 5). Two thirds of large company financed research, and 2/5 of small company financed R&D, are performed

inhouse, adding to a total of 2/3 of all R&D expenditures. About 1/3 is acquired externally.

Figure 5: R&D expenditures 1997, by company size and performing unit. Total = 393 million NOKs. Source: NIFU (ed.), 1999: Det norske Forskningssystemet - statistikk og indikatorer 1999, Norges Forskningsråd, Oslo



Innovation costs

We have argued that R&D is just one of several sources of knowledge for the food processing industry, in line with the systemic approach presented in the Introduction of the paper. We will now raise this argument to a more concrete level, by examining the ways in which the food industry actually spends money when innovating, then comparing the findings to other Norwegian industries.

Figure 6 show an overview of the distribution of innovation costs in a variety of Norwegian industries. Several points distinguish the food industry:

A high proportion of expenditure on investments (for instance, capital goods expenditure, machinery and equipment). Investment costs account for roughly 50% of total innovation costs, higher than the corresponding share for investment-intensive industries such as pulp and paper and metal production.

The high proportion (compared to all other industries) of expenditure devoted to market analyses.

A higher than average portion of innovation costs taken up by 'running costs', such as training and repairs.

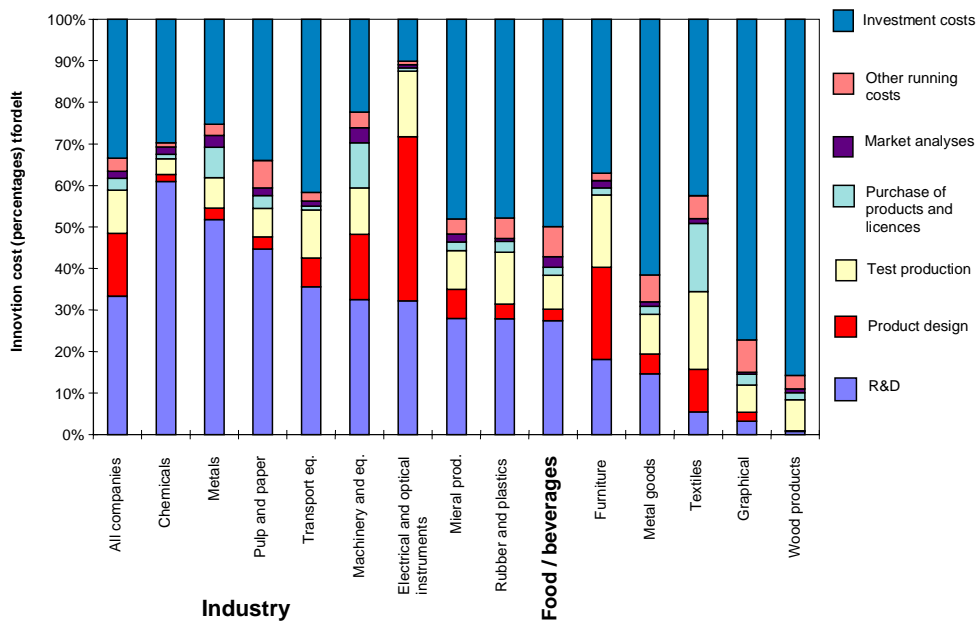
A smaller emphasis on product design than in most other industries. This is perhaps an intriguing result, given that food companies are producing goods for consumer markets.

R&D expenditure represents about 1/3 of total innovation expenditure. This is roughly average for Norwegian manufacturing.

In sum, what we find is a confirmation of the conclusion that, relatively speaking, R&D represents one part of the story of how food companies acquire knowledge. Other important innovation stimulants are new machinery and, compared with other industries, market analyses.

The industry also has a relatively high proportion of innovation expenditure taken up by ‘running costs’. As pointed out in the introduction above, the industry has traditionally attracted employees with relatively low levels of formal skills. It may be that this high running cost figure is an indication of a greater need for in-house learning processes, such as training in the handling and maintenance of new machinery and equipment. (See for example the Ringnes case study.)

Figure 6: Investment cost shares in different Norwegian industries 1992. Source: Community Innovation Survey, Norway, STEP Group / SSB.



Information-based sources of innovation

So far we have looked at innovation patterns in Norwegian food processing companies. However, a central aim of this paper is to analyse the particular role and position of the Oslo region’s food processing industry. The essential argument is that a regionally integrated innovation system is more likely to be successful in developing and introducing innovations. Theoretically, a localised system should be better suited to propelling innovation, since innovation is a complex activity, involving many disparate knowledge suppliers; physical proximity facilitates communication and personal contact.

We have already highlighted some core features of the regional food industry in the Oslo area. We have noted the high concentration of co-operative headquarters and core knowledge suppliers - such as Matforsk, NLH, Veterinærinstituttet, and Ernæringsinstituttet at the University of Oslo - located in this region, in addition to machinery vendors and market consultants (for instance, public relations companies, and market research companies like BI, SIFO, NILF and ACNielsen). (See the next chapter for further detail.)

One way of illustrating the unique position of Oslo region food companies - and the differences between the Oslo-based companies and those in the rest of the country - is to examine the statistical data recording the key sources of innovation according to the innovating companies themselves. Figure 7 shows the proportion of innovative food enterprises reporting information sources as being either 'important' or 'very important' to innovation within the company, both for Oslo-based companies and for those in other regions. The term 'information sources' refers to a wide variety of sources such as fairs and exhibitions, computer-based information networks, conferences, meetings, journals, patent disclosures, research institutes, universities and colleges, suppliers, consultants, customers, competitors, and people within the company or enterprise itself.

The chart reveals several interesting differences between the Oslo region and the country as a whole in terms of the weighting given to different sources of information, the most striking being that Oslo companies, on average, place a higher importance on almost all information sources than that placed by their provincial counterparts. This can be interpreted in two ways. Firstly, it may be that food companies in Oslo use a wider spectrum of sources (that is, a quantitatively higher number of sources) than is usual for Norwegian food companies. Alternatively, it is possible that they do not use a greater number of information sources, but that the impact of these information sources on the Oslo-based companies is greater than is common in the rest of the country.

The source for which there is the greatest discrepancy, in terms of the importance attached to it by Oslo-based companies relative to the national average, is Universities and colleges. The proportion of companies rating this source as 'important' or 'very important' is almost 50% higher in the Oslo region. Research institutes are also rated on average as being of higher importance among Oslo companies than among those of other regions; however, the discrepancy for this source is not much higher than the average discrepancy for all sources mentioned (16%, versus 13% for all sources).

Oslo companies rate fairs and exhibitions, conferences, meetings, and journals as being important more often than their national competitors do. The difference is about 30% in these cases. The same applies to the rating of computer-based information, however this kind of information generally scores a low rating: less than 20% of the companies rate this as an important or very important source of innovation.

Information from suppliers is also reported by the food companies as being important to innovation: about 80% of innovative food companies report that suppliers have been either important or very important to innovation. The same figure applies for information from customers as a source of innovation, and the corresponding figures for information stemming from inside the company or enterprise group are also very high.

In summary, the three most important information-based sources of innovation reported by Oslo-based food companies – as compared with the whole country - are: Universities or higher education institutions³⁸,

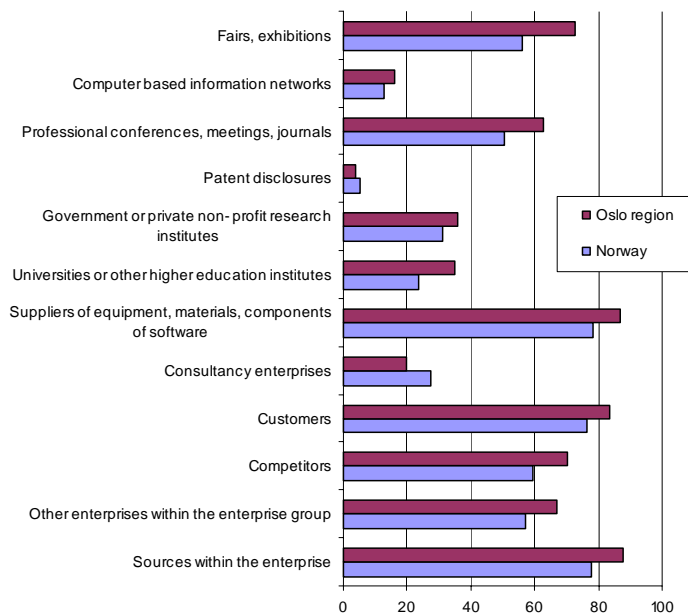
³⁸ Table 6 shows which institutions this refers to

Fairs and exhibitions,

Professional conferences, meetings and journals.

Patent disclosures and digital information are rarely rated as important sources of innovation, and neither are external consultancy services. Consultancy services is one of the few information sources that Oslo based companies tend to rate as less important than do food companies in the rest of Norway.

Figure 7: Share of innovative food enterprises reporting information sources as important or very important to innovation in the company, Oslo and Norway, weighted numbers, 1997³⁹. Source: Community Innovation Survey, 1997, STEP Group / SSB



Technological co-operation

We have looked at the important information-based sources of innovation by food companies, with focus on the difference between the Oslo region and Norway. One of the findings was that Oslo-based companies tend to rate fairs, exhibitions and conferences as more important stimulants to innovation than other companies do. Does this mean that Oslo companies have a more international perspective in their approach to the innovation process?

One way of answering this question is to investigate the extent to which Oslo-based food companies collaborate with foreign entities for technological development, compared to companies in the rest of the country. Another argument for investigating patterns of technological co-operation is that it will tell us something about the partners these Oslo-based companies actually co-operate with in terms of technological development; their nature, their names, and their locations.

³⁹ Please note that the results are based on few cases; N = 11 (Oslo region) and 79 (Norway). The same applies for Figure 8 and Figure 9.

As Figure 8 and Figure 9 show, Oslo-based food companies are more outward-looking in their approach than those in other regions, when measured by the proportion of companies engaging in international technological co-operation. Oslo companies co-operate more often with foreign research institutes, universities, suppliers and consultancies, as well as foreign divisions of the same enterprise.

In terms of technological co-operation on a purely national level, the picture is not so conclusive, although we can see that Oslo companies more often engage in technological co-operation with research institutes and suppliers of machinery.

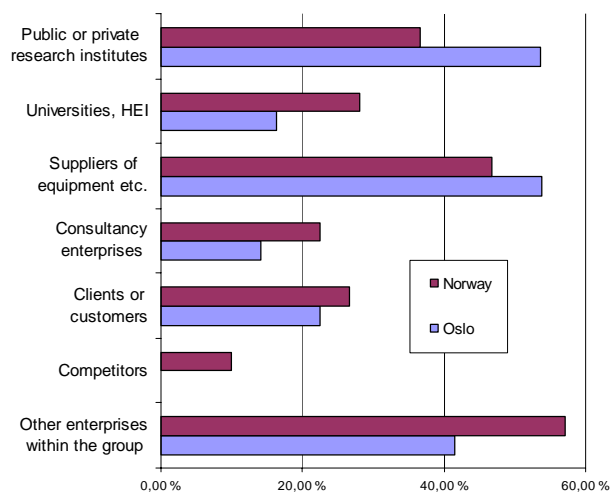
In summary, the two most important *national* innovation partners for Oslo food companies - compared to the country as a whole - are:

- ✓ Public and private research institutes⁴⁰,
- ✓ Suppliers of equipment.

The most important *foreign* partners - compared to the country as a whole – are:

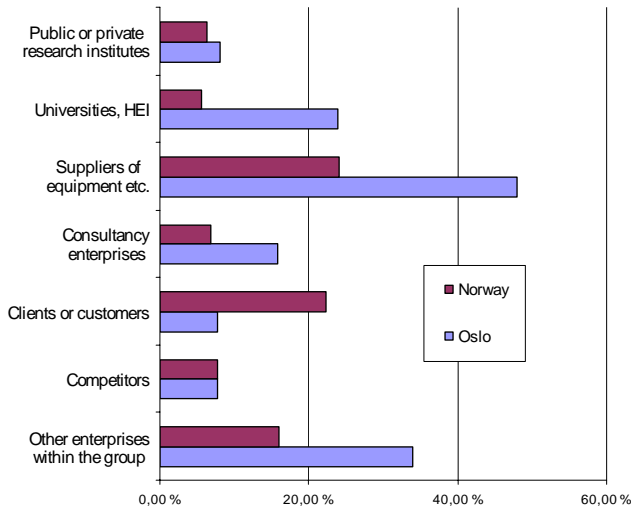
- ✓ Universities and higher education institutions,
- ✓ Consultancy enterprises,
- ✓ Suppliers of equipment and /or other units within the group.

Figure 8: Domestic technological co-operation: Share of innovative food companies reporting technological co-operation with Norwegian partners (weighted figures).
Source: Community Innovation Survey 1997, STEP Group / SSB



⁴⁰ To see which partners this involves, please refer to Table 6

Figure 9: Foreign technological co-operation: : Share of innovative food companies reporting technological co-operation with foreign partners (weighted figures).
Source: Community Innovation Survey 1997, STEP Group / SSB



Summary

In this chapter we have attempted to illustrate central features of the innovation process in food companies. The most important finding is that food companies innovate just as often as is average for Norwegian manufacturing companies. We have shown that R&D level is high compared to international competitors, but that R&D is just one part of a larger picture in terms of stimulants to innovation in food companies. The proportion of gross value of production devoted to R&D by Norwegian food companies was, in 1993, higher than in countries like France, Denmark, the USA and Great Britain.

About 1/3 of total innovation expenditure is normally spent on R&D. For the food industry, capital equipment and market research are also important input factors compared to the rest of Norwegian industry. When asked which information sources they regard as most important to innovation, Oslo food companies quote sources such as universities and colleges, fairs, exhibitions, conferences and journals more frequently than the national average for food companies. Most significantly, Oslo-based companies name research institutions as being important knowledge suppliers for their innovation process more frequently than food companies in other regions.

We have also shown that Oslo-based food companies are more open to technological co-operation with foreign partners than other Norwegian food companies. This applies in particular to collaboration with universities and colleges, but also to collaboration with foreign suppliers of machinery and equipment, and with other enterprises within the same group. Crucially, Oslo-based food companies are far more open to co-operation with research environments – such as universities and higher education institutions – than other food companies in Norway. In terms of the

use of domestic research institutes, Oslo-based food companies again score more highly than their national competitors; more than 50% of the Oslo companies reported having used such institutions during the last three years (1993-1996).

3. The knowledge system

Introduction

In the previous chapter we analysed innovation patterns in the food industry. We saw that innovation in food companies was broadly centred around three activities: market research, which was seen to play an important role compared with other Norwegian industries, and the core innovative activities of R&D, and the implementation of acquired machinery.

Technological developments are key to understanding the shaping of the food industry. It is important to distinguish between *technique* on the one hand and *technology* on the other. Technology is more than techniques; the ‘logy’ in the word ‘technology’ implies not just techniques, but *knowledge* of the way in which these techniques are performed. This chapter looks more closely at the role of this knowledge in the food industry. The analysis is separated into two parts. Firstly, we will describe the formal competencies within the industry. We will then look more closely at the knowledge bases within the industry, by which we mean the activities, technologies and knowledge used within the food industry.

Measuring the level of formal knowledge in an industry can be a coarse and problematic way of measuring real competencies. A person trained on the factory floor can be equally efficient or skilled as someone who has been formally trained in a further school or higher education institution. Although it may be the only statistical means of ‘knowledge mapping’ that is available to us, by measuring formal knowledge we run the risk of underestimating the importance of informal competencies. The food industry is clearly an industry in which informal knowledge and learning-by-doing are very important to the efficiency of daily production activities.

However, the best argument for using formal knowledge as a proxy for overall knowledge levels within an industry is that people with formal skills are ‘trained for training’. That is to say, they have a better capacity for absorbing new information in a systematic way, they may be more interested in learning, and they may have a basic knowledge platform from which they can learn to perform certain operations quickly while others would have to learn them from scratch. Many would disagree with this view, and we shall not pursue the debate in full here. However, we do acknowledge the inherent weaknesses in the use of formal knowledge as a proxy for industry-wide competency levels.

Formal knowledge in the industry

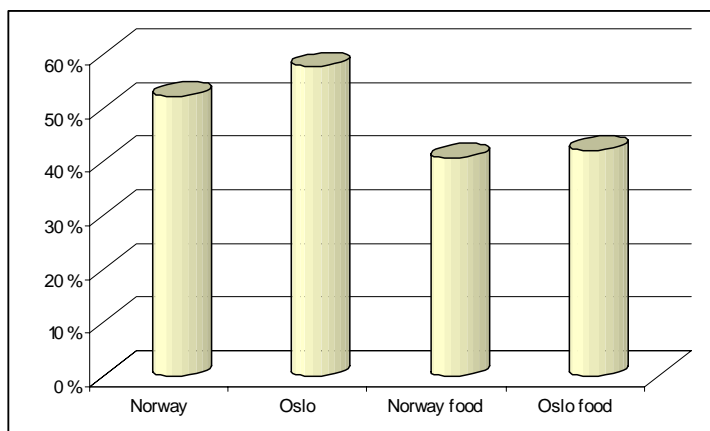
One of the clear challenges that the food industry faces is a shortage of formally skilled people within the workforce. According to statistics and interviews, the food industry - small companies in particular - employ relatively few people who have finished further school (videregående). However, this should not necessarily be identified as a ‘problem’. Some companies say that they do not regard low formal

skill levels as a significant problem. Employees are trained on the factory floor, by their colleagues or their managers. Some tasks are so company-specific (see case-study of Nøttefabrikken) that they have no parallel in public education, while other tasks are regarded as being so simple to perform that no formal background is required (see case-study of Majonæsfabrikken).

Because innovation by definition implies doing something new, in many cases it requires some capacity for systematic learning. The ability to learn is not evenly distributed among employees, and formal skills *can* be regarded as a proxy for the degree to which employees have been “trained to train”. Figure 10 shows the proportion of employees with further school qualification or higher in all manufacturing companies and food companies - for Norway as a whole, and for the Oslo region - respectively.

The chart shows us two interesting things. Firstly, food companies in Oslo have a higher proportion of educated employees on their staff than the average for all food companies in Norway. However, the difference is rather small: 42.1% as opposed to 40.6%. More interestingly, the chart shows that Oslo-based manufacturing companies *in general* have a higher proportion of educated employees than their national competitors. The proportion in Oslo is 55%, compared to 50% for all Norwegian manufacturing companies. So if we adjust for Oslo’s apparent status as a centre for formal skills, the Oslo region food industry scores relatively poorly in relation to the country as a whole. The difference between manufacturing companies in Oslo and in Norway as a whole, in terms of the proportion of employees with further school education, is 10%. In the same terms, the difference between food companies in Oslo and Norway as a whole is only 4%. This means that the formal education level in the food industry in Oslo is lower than we would expect when taking into account the region’s collective education level, although the differences are small.

Figure 10: Percentages of employees with further school qualification or higher in, respectively, manufacturing industries in Norway, manufacturing industries in Oslo, food companies in Norway, and food companies in the Oslo region. Source: Employment register, 1996, STEP Group / SSB.



Formal skills in small Oslo-based companies

Although the above findings might lead us to assume that small companies in the Oslo region have the lowest proportion of formally skilled employees, this is not in fact the case. The percentage of employees with further school qualifications is highest in companies with less than 50 employees, and lowest in companies with 200 or more employees. The proportion for small companies is 46%, compared to 41% for the largest companies. Companies with 50-199 employees have a percentage that is average for the region: 42%.

Table 5: Proportion of employees with further school or higher qualifications in Oslo-based companies, by company size. Source: Employment register, 1996, STEP Group / SSB.

Company size (no. of empl.)	1-49	50-199	200 +	All
Percentage of employees with further school	46	42	41	42

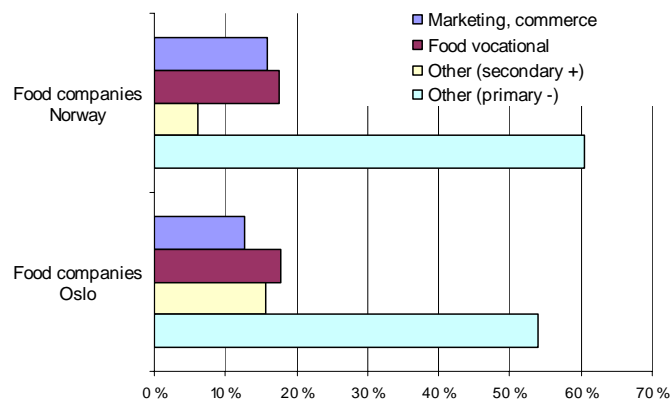
There are several possible explanations for this result. It may be that large companies, to a greater extent than small companies, tend to internalise tasks that traditionally require only low levels of formal training, such as transport and cleaning. Another explanation might be that small companies employ a larger proportion of younger people, who are in general more likely to have completed further school than older workers. There are also indications that the largest companies deliberately and systematically hire unskilled women and non-European immigrants (see Ringnes case-study).

What types of formal skills are found in Oslo companies, and are there any differences between Oslo and rest of the country with respect to these skill profiles? Our research findings suggest that slight differences do exist. In our analysis we have chosen to divide employees into four groups according to their formal skills. These groups are i) Market and commerce-related training, ii) Food-related/vocational training, iii) Other I (further school or higher qualification), and iv) Other II (secondary or lower). The *Market and commerce* category includes further school studies and higher education in subjects such as ‘handel og kontorlag’ (trade and office studies), ‘regnskapslinje’ (accountancy), ‘markedsføringslinje’ (marketing) and ‘siviløkonomiutdanning’ (economic development). *Food/vocational training* includes school qualifications in areas such as ‘maskin og mekanikerlinje’ (machines & mechanic training), ‘pølsemakerutdanning’ (sausage-making) ‘fiskeindustrifag’ (fishing industry studies), ‘bakere’ (baking), ‘husmorskoleutdanning’ (home economics) and ‘konditorer’. The third category, *Other I (Further and higher)* includes further school or higher qualifications not covered elsewhere. *Other II* include secondary school or lower.

What we find, beyond the fact that a larger proportion of food employees in the Oslo region have further school or higher education than food employees in the rest of the country, is that a higher percentage of food employees in Oslo have qualifications in the *market and commerce* category than in rest of the country. The proportion in Oslo is 16%, while the corresponding figure for the rest of the country is 12.6% (Figure 11).

There is no such difference in the proportions of employees with vocational training in food-related subjects. The percentages are almost identical (17.4% for Norway and 17.7% for Oslo). For employees with less relevant education (that is, outside the *market and commerce* or *food/vocational* categories), we find that only 6% of employees in Norwegian food companies have finished further school. The same figure for Oslo is 15.5%⁴¹.

Figure 11: Types of formal skills in food companies in Norway and Oslo⁴¹. Source: Employment register, 1996, STEP Group / SSB



Knowledge mapping

The knowledge base of the industry

Due to the sheer magnitude and complexity of the industry, the knowledge base of the Norwegian food industry is actually made up of multiple knowledge bases, drawing on a variety of inputs from a breadth of disciplines that few other Norwegian industries have to balance. Food production encompasses such diverse activities as the selection and preparation of raw materials, processing, preservation and storing, packaging, wrapping and coating, hygiene and safety, quality and nutrition, quality control and quality documentation, transport and distribution, and trading, sales and marketing. As the Lindgaard-Christensen report states: “*The [food] industry is already near the forefront of industries in the application of a breadth of different scientific advances, i.e. innovating by means of ‘new combinations’ of scientific disciplines*” (pp. 1-2).

We have shown that Oslo-based food companies are more frequent users of scientific inputs than provincial food companies (see for example Figure 7, Figure 8 and Figure 9). A survey performed in the national food industry by STEP Group in 1997 highlights the extensive use of research environments, and illustrates the way in which this complex system works in “real life”. In the survey, Norwegian food companies were asked which research environments they regarded as being

⁴¹ Figures only include figures for the 40 most common education directions in each region (Oslo and Norway). For Norway as a whole, this includes 30.000 of 55.000 employees. For Oslo, this includes 1709 of 7.500 employees.

important knowledge providers to their field of production. The results are shown in Table 2. The table lists the main knowledge areas in the food industry, along with over 30 institutions that are important knowledge providers in these areas.

*Table 6: Dominant technological areas and scientific knowledge developers for the Norwegian food industry (Oslo-based companies in bold)*⁴²

	<i>Selection and preparation of raw materials</i>	<i>Processing</i>	<i>Preservation and storing</i>	<i>Packing, wrapping and coating</i>	<i>Hygiene and safety</i>	<i>Quality and nutrition</i>	<i>Quality control and quality documentation</i>	<i>Transport and distribution</i>	<i>Trading, marketing and sale</i>
<i>Techn. area</i>									
<i>Knowledge suppliers</i>	Matforsk , Norconserv, NLH , NVH , Jordforsk , Planteforsk , Felleskjøpets forutvikling , Havforskings-instituttet, Norsk svineavlslag , Norges fiskerihøgskole, Fiskeriforskning, UiO (biol.) , NIVA	Matforsk , Norconserv, NLH , NVH , NTNU, SINTEF, Norske Meierier , Potetindustrienes Laboratorium, UIT (biologi og geologi)	NLH , NVH , Matforsk , Norconserv, SINTEF, NTNU, Norsk Kjøtt , TINE	NVH , Norske Meierier , Matforsk , Norconserv, NLH	Norsk Kjøtt , Norske Meierier , Potetindustriens Laboratorium, NVH , Matforsk , NLH , SSF, Plantevetem	Matforsk , Norconserv, NLH , UiO , NVH , Norsk Kjøtt , Norske Meierier , Fiskeridirektoratet, Ernæringsinstituttet , Felleskjøpets forutvikling	Norske Meierier , kontrollinstituttet for meieriprodukter , Norconserv, NVH , NLH , Matforsk	SINTEF, NTNU, NLH , Matforsk , NVH , UiO	BI , NLH , SIFO , NILF , Fiskeriforsk, SNF (fiskeriøkonomi), Norges Fiskerihøgskole, NMH , HiH, AC-Nielsen , MMI

Several interesting points emerge from this table. Firstly, we see that most of the more frequent knowledge suppliers are located in the Oslo region. These knowledge suppliers include Jordforsk (Ås), Planteforsk (Ås), Matforsk (Ås), Norges Landbrukshøgskole/NLH (Ås), Norges Veterinærhøgskole/NVH (Oslo) and the University of Oslo (UiO; incl. Ernæringsinstituttet). The list also includes Oslo-based industry-owned research facilities such as TINE Norske Meierier and Norsk Kjøtt.

Secondly, it seems that the most extensive supplier of knowledge to the food industry is Matforsk, located at Ås, which according to the table supplies almost all food-related activities with scientific knowledge.

Thirdly, we see that most of the knowledge providers are institutions that traditionally operate within the 'agrofood' sector of the food industry; Jordforsk, Planteforsk, NLH, Potetindustriens landsforening, Norske Meierier, Norsk Kjøtt and Kontrollinstituttet for meieriprodukter.

Summary

This chapter has examined the knowledge systems within the Oslo region's food industry. We have shown that food processing companies in the Oslo region have a slightly higher proportion of formally skilled/qualified employees than food companies in the rest of the country, but this discrepancy becomes negligible when we take into account the generally high education levels in the region. We have also seen that the percentage of employees with further school qualifications is highest in the smallest companies.

⁴² Based on STEP Group / Trine Bendix Knudsen et al. (1999), in Stortingsmelding (The Government's report to the Storting), 39, 1998/99. Complimentary information added from the Norwegian Research Council project catalogue 1999 (biotechnology and processing)

However, the percentage of the labour force in this industry educated to secondary school level only is still over 50%. This may mean that food companies devote a high level of resources to in-house training. As documented in Chapter 2, innovation-efforts in food companies are, with relative frequency, categorised under 'running expenses', which includes learning and skills-training. The case of Ringnes, where internal skills-training policy was a deliberately accounted for in the development of the new factory at Gjelleråsen illustrates this emphasis.

Another interesting aspect of the food industry's knowledge system is the immense volume of research activity undertaken in the field. This paper has noted the location of several research institutes in the Oslo region, and argued that this has some significance to the food industry in the region. *Food related R&D* is produced and acquired from the Ås complex, the largest supplier of research and technology to food companies in Norway - working in areas such as selection and preparation of raw materials, processing, preservation and storing, packaging, wrapping and coating, hygiene and safety, quality and nutrition, and quality control and quality documentation. It is also important to acknowledge the significance of major *market research* entities located in the Oslo region, such as BI, ACNielsen, SIFO, Matforsk, MMI and NILF, providing intelligence on consumer trends, transport and distribution, trading, and sales and marketing, areas which are of particular and increasing importance to the food industry.

There are contrasting indications of the extent to which these environments are actually used by food processing companies in Oslo. On the one hand, the statistical surveys indicate that Oslo-based companies are more efficient at using these knowledge suppliers than other Norwegian food companies. The largest co-operatives like TINE and Norsk Kjøtt have permanent researchers located at Ås (NLH). Matforsk report that, increasingly, they are directly involved in industrial research (see case-study of Matforsk). Statistics also show that small food companies in a larger extent than national average spend money on R&D.

On the other hand, and perhaps not surprisingly, interviews reveal that small companies often have little contact with research environments. Some of the larger companies have also said that they have 'too little' or even no contact with the research environments. As we saw in Figure 8 and Figure 9, many Oslo-based companies have contact with international research environments, probably through their parent entities (as in the cases of Freia, owned by Kraft, and Nestlé).

The conclusions of this chapter can be summarised as follows: the use of scientific knowledge is increasing in the industry, and although the smaller companies have a relatively high proportion of formally skilled employees, they lack the contact with research environments that larger enterprises enjoy. The extent to which this affects the development of the smaller companies is debateable. Reports from the companies themselves reveal that they regard other factors as being of greater significance to their business development, with many companies mentioning in particular the hegemony of the four grocery chains (see Chapter 1).

Another more long-term aspect of the 'scientification' of food processing is the question of whether this development will lead to an increased distance and detachment between the work force and the product, with informal skills and 'silent' product knowledge (as in the case of roasting in Nøttefabrikken) being gradually replaced by formal education, leading to more research-oriented employment and

increasingly 'scientific' production processes. Such trends have been noted in, for example, the machinery industry during recent decades (Pedersen, current work in doctoral thesis, STEP Group). Similar developments in the food industry would have direct implications for localisation in the industry. When production becomes less reliant on the individual and his or her historically acquired skills in the factory hall - the concrete, in-house knowledge of how to roast the nuts, the correct proportion of egg yolk in the mayonnaise salad, how to repair the machine when it breaks down, etc. - and the production process therefore primarily depends not on the local worker but on external and generic knowledge, production will become more flexible with regard to location.

Labour responses to these developments might mimic the case of Ringnes (see case-study), where the labour union deliberately initiated a process of control-taking over the means of production in order to increase their members' job security. After a continual process of training and certification of workers, the Ringnes employees now have the skills to repair and maintain the production equipment, thereby maintaining their importance to the production process. From the company's perspective, these workers now possess direct production knowledge that is difficult to find elsewhere, making relocation an unattractive prospect. By contrast, the announced relocation of Sætre biscuits⁴³ can be seen as a case in which the local workforce is no longer regarded as an important asset to production, the key production knowledge being easily transferable to Swedish workers in the new location.

⁴³ Aftenposten Sept. 1999. The company announced they planned to move production from Akershus to Sweden.

4. How does innovation provide a competitive advantage?

Introduction

According to the previously cited European innovation survey (Lindgaard Christensen et al 1996), the food industry is distinguished by a high number of radical new products that create a temporary monopoly for the innovator. This is particularly the case for Norwegian companies. The survey revealed that innovating Norwegian companies are at the European forefront in terms of the frequency with which they introduce radical innovations. 71% of all innovating Norwegian food companies introduced innovations that were new to the industry in the period 1990-1992. The average for food companies in ten surveyed European countries was 37%; other countries' figures included Italy with 48%, Belgium and Denmark with 51% and 59% respectively, and Portugal with 40%.

However, there are many difficulties involved in demonstrating that real competitive advantages result necessarily from technological innovations in the food industry. Firstly, extraordinary gains from radical innovations may be short-lived. This is because food products and processes are relatively easy to imitate.⁴⁴ Studies have shown that, unlike companies in high-tech industries, non-innovating food companies may be able to obtain the same extra-ordinary gains using other methods, such as differentiation of existing products, advertising, or control of natural resources. The EU report concludes that "*the association between innovativeness and profitability in food-processing is likely to be more tenuous than in high-tech industries*" (p. 61). In other words, there is no direct or obvious correlation between technological innovation and competitive advantage in the food industry.

Another hindrance is the fact that food consumption is heavily influenced by tradition: customers tend to buy products that they are familiar with, and that they trust. The historical emphasis on branding in the food industry (particularly in the case of beverages) underlines this point: producers like to build up and exploit a brand name rather than attempt to introduce new products with any regularity. A case in point occurred in 1994, when the agrofood industry received a government grant of NOK 1 billion to stimulate 'structural changes' in the industry, the intention being to make the industry more prepared for - and adapted to - increased competition in case of a possible Norwegian entry into the European Union. When asked how they had used the money - about E 125 million - companies predominantly cited product quality and customer relationships as the two main targeted areas of improvement. Of 24 listed objectives, the four that ranked highest in the survey results according to their strategic importance to the companies were: i) product quality, ii) quality and hygiene in the production process, iii) customer relations and iv) raw material quality. Development of new products, or development and enhancement of existing product portfolios, was ranked among the four least important objectives⁴⁵.

⁴⁴ OECD 1988, Industrial revival through technology, OECD, Paris

⁴⁵ ECON 1997; *Evaluering av omstillingstiltakene for den landbruksbaserte næringsmiddelindustrien*, Sluttrapport, fase 2, p. 25. From a total of 160 companies, 40 percent were located in the Oslo region.

A third factor making it difficult to point out ways in which technological innovation provides the Oslo-based food companies with a competitive edge, is company heterogeneity. Companies are heterogeneous in terms of both activity and size. The industry is dominated by three large sub-sectors, with separate knowledge bases and dynamics; beverage production, meat production, and production of pastry and miscellaneous products (the latter including diversified products such as biscuits, nuts, tea, chocolate, etc.). There are also great differences in the ways in which smaller and larger companies perform innovations. Large companies may draw on several advanced knowledge suppliers, as in the case of Tine (see box *Tine*), while innovation in small companies is often less formal and less 'scientific' (see box *Majonæsfabrikken*).

Still, it is possible to illustrate some ways in which product innovation does make Oslo food companies competitive. The example provided of product development in *Majonæsfabrikken* illustrates how innovation can be performed in small food companies (see box). Product innovation in *Majonæsfabrikken* is informal and 'low-tech'; it is based on tacit skills and places little emphasis on formal expertise or direct

Majonæsfabrikken

Majonæsfabrikken is a family-owned artisan factory with 9 employees, established in 1923 and located in Industrigaten in Oslo (named after the many handicraft shops, repair shops and small factories that used to be - and some of them still are - located in this street). Majonæsfabrikken produces 'private brand' quality majonese and majonese-based salads, like tunafish salads, shrimp salads etc. They deliver the products themselves to grocery stores in the greater Oslo area, and had in 1998 a turnover on 8 million NOKs.

Developing a new product happens on quite informal basis. There are two sources of information to new products, ideas from the production manager, or ideas from competitors products - or a combination of the two sources. Copying competitors salads or ingredients is a plain and informal process. Competitors products are purchased in a grocery store, and by tasting and sniffing the product, ingredients are easily recognised. Then the factory decides to produce or develop those salads 'they believe in'. The latest development is a tunafish-salad, introduced spring 1999.

One of the most hampering factor to product innovation is the marked power of the four dominant grocery chains. The grocery shop manager has little influence on the product portfolio in his own shop, and however interesting a new product is, most shops are obliged to sell national salad brands propelled by TV commercials (like Denja or Mills' Delikat). Majonæsfabrikken therefor delivers it's products to grocery shops with a wide or specialised product portfolio, like ICA, Jens Evensen, Seven Eleven, Matpakkekompaniet, Plenty, Servicemat and Smør-Petersen.

use of advanced technological knowledge. The case illustrates very well the advantages enjoyed by small companies in the food industry: competitors' innovations can be easily copied, and their product-advantages thereby easily nullified. The case also casts doubt over the extent to which - and the length of time for which - innovation leads to competitive advantages in the food industry, at least in terms of product innovation. According to the manager at Majonæsfabrikken, the innovation process has little direct effect on competition compared to other production factors, such as genuine product quality (and quality of ingredients used), and distribution. The company claims that their competitive edge relies on three 'constant' factors: i) the use of quality ingredients in their mayonnaise, such as oil and egg-yolk (in contrast to what the manager describes as a constant degradation of

mass-produced salads, with starch increasingly used as a cheap substitute for other ingredients in order to lower the price), ii) the use of 'private brands' for all products (a matrix label printer in the company's office prints labels for the salad boxes bearing the grocery shop's own name, thereby making the salad appear 'home-made'), and iii) the use of salespeople to promote and distribute products among local grocery stores.

According to the European innovation survey, there has been a dramatic swing away from product push to market pull in recent decades. This is illustrated by the case of TINE Norske Meierier, where the substantial use of external market consultants (trend analysts, market monitors, public relations agents and other consultants) created the stimulus for introducing a new product. However, it is our opinion that in looking for ways in which innovation provides competitive advantage in the food industry, we must extend our search beyond product development. What factors, then, are important to innovation?

What factors are important to innovation?

As highlighted above, there are big differences in the ways in which innovation takes place in different sectors, and in companies of different size. In terms of product innovation, interviews have shown that while small companies tend to perform incremental innovations based on the use of informal knowledge, larger companies will use their financial resources to buy in external knowledge, for instance from consultancies (and to some extent scientific knowledge also), when developing a radically new product. The case-study of *Majonæsfabrikken* serves as a good example of incremental product innovation based on informal inputs.

The example of *TINE Norske Meierier's* development of the Ox drink, a milk-based product aimed at young people, is another illustration of this point (see box). The product development process took several years and involved the use of public relations companies, external design consultancies, trend consultants, market analysts and high-precision printing companies, as well as TINE's own research and marketing divisions. Most of the companies used were located in the Oslo region. However, despite the large number of printing companies in the Oslo region, the need for high-precision printing of the milk dispensers, in a sterile environment, led to Elopak (the manufacturer of the dispensers) contracting the printing out to a foreign company.

This contrast in the ways in which innovation is performed in large and small companies in the food industry is almost archetypal. Differences are commonly found in several aspects of the innovation process: the resource inputs used to achieve innovation, the proportion of research-based innovation, the degree to which innovation is 'radical' (new products vs. incremental change of existing products), and the number of people and institutions involved in the innovation.

The two examples also illustrate quite another aspect of innovation in food industries, namely, the way in which small and niche-oriented companies can be marginalized by the force of the large companies, particularly within such a quaternary retail structure as exists in Norway⁴⁶. There are several reasons why large companies are more adapted to the retail structure than niche companies:

Den Lille Nøttefabrikken

Den Lille Nøttefabrikken produces quality snacks, dried fruits and nuts. 18 persons work in the factory, located at Hauketo in Oslo. Few of the employees have been around for more than 10 years. Turnover in 1999 will be high; about 50 million NOKs. The company imports raw material, mainly from South America, through a stable pool of Dutch traders. The products are controlled, roasted (nuts) and packed in Oslo, before transported to kiosks, gas stations and grocery shops all over Norway through a network of regionally based sales persons.

According to the company's market director, the company's competitive edge lies within the process of roasting and burning, controlling, storing and packing imported raw materials. The factory's success is also related to their focus on consistent use of brand name in presenting their products, together with a pleasant design on product display. For the consumer, the nuts and fruits are typically impulse products, presented with advanced and attractive graphical design on dispensers and boxes. The nut display units are made of bright wood and non-corrosive steel, and designed by the company itself and produced by a Oslo based carpenter company (Anker Schultz). The company logo is designed by Bruno Oldani, a well-known industry designer, also located in Oslo.

The employees in *Den Lille Nøttefabrikken* have little formal education, but are trained in controlling the ovens and tasting the products in the production hall. The factory was established in 1984 by Bjørn Holmsen, who works in production. When new loads of nuts arrive, Holmsen - with some of his colleagues - performs a test roasting and taste the production. If necessary, they change the oven settings (temperature, speed), in order to obtain an optimal result.

1. Large companies are retailer-suited in terms of volume; they produce quantities large enough to be attractive to the large, homogenous market of the dominant retail chains.
2. They are retailer-suited in their market approach; larger companies have the economic resources to provide both new and established products with a broad and voluminous marketing back-up, consisting of market analysis, television commercials and other PR work.
3. They are retailer-suited in terms of price/quality ratio: The extreme focus on price among retail chains has diminished the retailers' interest in niche products and higher quality products. (According to an investigation performed by the employee organisation NIL in 1995, price pressure from the retail chains is so tough that it leads some producers to use inferior raw materials⁴⁷.)

⁴⁶ For more reading, see Dulsrud, Arne (SIFO), *Markedstrender og utviklingen i distribusjonsmønstret*, in Odd Jarl Borch and Egil Petter Stråte (eds.), *Matvareindustrien, mellom marked og politikk*, Tano Aschehoug 1999 Oslo

⁴⁷ Bull-Gjertsen, Berit, 1995, *Innovasjonsvirksomheten i Næringsmiddelindustrien*, Næringsmiddelindustriens Landsforening, Aug./Sept. 1995.

4. Large companies (Nestlé and Ringnes for instance) have separate marketing divisions and product development divisions. These divisions are responsible for monitoring market trends and competitors' product developments as well as developing new products.

AS Nestlé Norge

The head office of AS Nestlé Norge is located at Billingstadsletta in Akershus. The establishment employs about 100 persons, in addition to production factories in Hammerfest and Hamar. Nestlé is Swiss owned, and the worlds largest food company, with global brands as Lion, Maggi, Nescafé and Nesquik in their portfolio, of course in addition to Nestlé baby food.

Innovation activities are less and less a local matter, says the market director. Earlier, much was controlled locally, but now strategic decisions are increasingly taken on an international level. Product development takes place in the enterprise's Swiss research laboratories. Who gets to be sub suppliers are decided jointly by the Nordic Business Group of Nestlé. However, some aspects of production are still local. Public relations, market analysts and media are purchased local. Examples of such local suppliers are MMI, 4 fakta and ACNielsen. The Norwegian office is 'an ear to local trends and product developments', according to the market director.

In terms of knowledge development, AS Nestlé Norge gains benefits from being under the umbrella of a global company. In addition to international research laboratories, the company have both Nordic and international training schools and access to a testing factory for new products.

The role of people in the innovation process

Interviews from a variety of small companies indicate a distinct lack of focus on attracting educated people into the industry. According to Finn Messel at *Den Lille Nøttefabrikken*, one reason for this may be that few further-school educational subjects are geared towards food production. At both *Den Lille Nøttefabrikken* and *Majonæsfabrikken* - both very small companies - few employees have any relevant education from further school. The companies do not regard this as a significant concern, as their production methods require no formal education or knowledge; all staff training takes place on the factory floor and is conducted by colleagues and managers.

The story in the larger companies is quite different. Nestlé have a deliberate strategy of attracting the best people. According to their marketing director, *Tine Norske Meierier* would, in the days when they had a monopoly on the production of milk and milk products, attract "everyone in Norway with milk related education", although they now face some competition - first and foremost from *Synnøve Finden* - in attracting educated staff. Indeed, some of their key personnel have defected to

TINE Norske Meierier

TINE Norske Meierier is the largest producer of milk and milk products in Norway. It is organised as a co-operative, owned by local milk producers. TINE has two research labs, in addition to Husdyrkontrollen located in Ås Research Park, all of them employing about 100 persons.

TINEs latest and biggest product innovation was introducing Ox, a milk-based drink in magazine-inspired wrapping (including news text, short information, colorful pictures, cool design) and with unusual tastes (like milk with licorice taste), aimed at adolescents. TINE's field work was impressive. The trend consulting company Magic Hat supplied TINE with trend analysis. Both TINE's market division and research division were involved in developing the different tastes and visual shaping of the product. External consultancies performed youth panel tests and analyses, which concluded positive to the new product. People from the public relation company Bates Group was hired in to develop the basic design of the container. A separate web site was established for the product (<http://www.ox.no>). The container magazine was regularly changed by an external editor company. The need for a combination of detailed and precise printing, sterile containers and four different printings a year made the dispenser producer Elopak chose foreign printers.

The product turned out to be a failure. The development costs were big, and the young ones did not buy the product. The product was withdrawn from the shelves after five months. TINE's market director explains that the main reason for the failure was that adolescents do not respond the same way in a purchasing situation as they did in the tests.

Today, TINES major strategy is to build up an international brand name around their most-selling yellow cheese Jarlsberg.

Synnøve. However, *Tine* still has vibrant marketing and research departments, underlining their dominant position in attracting people with formal skills in the production of milk and associated products.

There are, then, very significant differences between the smallest companies and the largest companies in the industry. Large companies often have separate marketing divisions, with key personnel occupied in branding, trend monitoring, and so forth, as we have shown in the cases of TINE, Nestlé and Ringnes. These companies also have internal product development departments, sometimes (as in the case of Ringnes) employing highly educated and qualified people, such as chemists, who have tenable connections to the public research infrastructure.

The grocery chain group oligopoly

We mentioned above that companies often cite the power of the grocery chains as being a huge obstacle to new products reaching consumers. This is naturally regarded as a hindrance to new product development and innovation, particularly in the case of local or high quality products from small and medium-sized companies (see pp. 90). When asked to identify the biggest change in the food industry in the last four years, many companies responded: "increased grocery chain power". When asked

what was the biggest factor discouraging business development, they again answered "grocery chain power".

There is no doubt that the increase in the grocery-chains' power has profoundly affected the industry, and that the power of the retailers is immense. When Fjordland, a producer of prepared meals, received a fax from the Hakon Group retail chain stating that their products were too expensive and were being discontinued by the chain, 40% of Fjordland's turnover was wiped out overnight. Arranging a meeting with the grocery chain's marketing division can take months, according to survey respondents. One producer said that if a large supplier wants to introduce a new product to a retail chain, then that supplier must be prepared to have another of its products taken off the shelves. Another respondent even claimed that the chains made a living out of extortion.

However, the signals from the food processing industry are not uniform. Small companies naturally tend to emphasise the difficulties they have in breaking into the retail chains, and the tough competition they face from larger companies. However, some producers mention more positive aspects to the increased power of the chains. Firstly, the retail chains' power can be seen as a valuable check to the enormous power of the co-operatives in the agrofood sector (such as Norsk Kjøtt, Prior, etc.). Secondly, as several producers admit, the chains' power has actually resulted in lower food prices, which naturally benefits the consumer. Thirdly, price pressure from the chain groups may result in the use of different - and cheaper - ingredients. The degree to which this process affects food quality is not entirely clear, and it is a potentially emotive debate. Some claim that altered ingredients reduce food quality, while others claim the opposite. Fourthly, the retail chains actually create some demand for new products. Several independent sources have reported receiving direct invitations from retail chains to present them with new products or enhancements to existing products. This should be seen in combination with the chains' undoubted distribution capabilities: they have the ability to bring new products to all reasonably densely populated areas of Norway, representing an important and efficient way of bringing new products to market. A fifth point in favour of the retail chain groups is that they encompass a variety of shop profiles, from low-price stores carrying a basic selection of products - such as KIWI, Prix, RIMI and REMA - on one side of the scale, to more upmarket stores with slightly higher prices and a more varied product spectrum - such as Jens Evensen, MEGA and ICA - on the other. The latter group tend to be more open to new and/or specialised products than the former, and the shop-keeper have more influence on the product portfolio. So in summary, the relationship between the power of the retail chains and the difficulties associated with bringing new products to market is more complex than is sometimes claimed by suppliers.

Summary

As we have seen, is difficult to offer generic examples of the ways in which innovation can create a competitive edge. Product development is easy to imitate, and this fact has led to a steady increase in the use of private labels among the grocery chains. There are also strong conservative forces affecting consumers, resulting in a tendency to choose well-known or 'traditional' brands and products.

The food industry devotes a great deal of resources to pushing traditional products, particularly in areas such as beverages and chocolate.

There are, however, some further points relevant to this discussion. According to the divisional director of the Bio-production and Processing Division of the Norwegian Research Council, there are three key factors that make Norwegian food production competitive:

- i) Norway has a reputation for producing clean, high-quality food with few additives. Any movement towards products labelled with their country of origin would therefore benefit Norwegian companies.
- ii) Norway has traditionally been creative in its invention of foodstuffs.
- iii) Norwegian products have a rare and pleasant taste as a result of beneficial climatic conditions.

In the course of our analysis of dynamic factors which give the industry a competitive advantage, we found that innovation in the food industry is based on three core activities: research and development, implementation of new machinery, and marketing/market research. In several case-studies we have illustrated the ways in which different companies engage in innovation through the use of these knowledge sources. The immediate picture that emerges is one of a complex variety of knowledge-application methods among companies of different sizes, and among different sectors. The most striking difference is that between the smaller and larger companies. Large companies rely more on formal knowledge providers, such as internal marketing departments and dedicated product development divisions. The larger companies and co-operatives also benefit from scale-related advantages in their relationships with the grocery chains.

Another significant factor in our analysis of the relationship between innovation and competitive advantage is the industry's apparent preoccupation with product quality. In survey responses Nøttefabrikken and Majonæsfabrikken, both small companies, emphasised quality as their primary, driving concern. Nøttefabrikken produces roasted nuts, and each new shipment that arrives in Oslo is manually tasted and controlled. Majonæsfabrikken pointed to the high level of quality ingredients in their salads, compared to the mass-produced products of their competitors. The same emphasis on quality is echoed by the above-mentioned evaluation report on a recent government grant, most of the money having been spent on quality-enhancing measures.

To what extent will quality create a competitive advantage for the industry in the future, and which sectors of food production will remain local? Taking the case of AS Nestlé Norge as a starting point, there is no immediate reason to believe that quality production is a guarantee of continued activity. The company is currently reorganising and reducing its Norwegian activities (this reduction including the sale of Findus), and few corporate decisions are now made in Norway. The selection of equipment suppliers, production machines and raw materials is controlled on a Nordic level and is increasingly conducted internationally, as is the company's research activity. However it is interesting to note the activities that remain locally embedded. "We are ears and eyes for local trends", the company's marketing director says. Public relations services, market trend analysis, polls, and other marketing

services such as blindfold testing are still acquired and conducted within the Oslo region.

It seems, then, that labour force and market knowledge are among the more localised aspects of the regional food industry's innovation system. However, the role of people varies with company size, in parallel to the variation in the availability of formalised knowledge inputs. At Ringnes, for example, we saw how the largely unskilled labour force went through a process of in-house skill-acquisition and certification in order gain control of the means of production. At TINE, as at Ringnes and Nestlé, people employed in distinct research and marketing divisions are essential to the development of product innovations. At both TINE and Nestlé, externally purchased market knowledge has been an important input to the innovation process.

We have looked at the factors that are important to innovation, and the ways in which innovation and knowledge may enhance competitiveness. We will now take this one step further, and examine the directions in which technological development is actually going: this will be the subject of the next chapter.

5. Main technological trends in the food industry

Introduction

This section contains an overview of technological trends in the food industry. The chapter is based on interviews with Oslo-based companies, as well as secondary literature on the subject. We will examine private branding, science-based products and processes, new ingredients, new products, and changes in consumer trends.

We will then go on to look at the ways in which knowledge-transfer occurs in this industry, with particular focus on Oslo, before summarising our findings.

Increased complexity

A striking aspect of modern food production is the increasing volume of people, institutions and knowledge suppliers participating in the innovation process. Previously, innovation followed a more sequential course, with product changes often determined by, and enabled through, the installation of new production technology.

The innovation process today is far more complex. The number of knowledge suppliers has necessarily increased, as the implementation of product innovations in food processing has come to require knowledge of ingredients, nutrition, wrapping, market trends and developments, design, and marketing, as well as the ability to select and control increasingly advanced production technology such as robotics and digital production systems. The product development case-study of TINE illustrates this point. This leads us to the conclusion that for food companies, innovation is not just a creative process, but also depends to a large degree on system management.

Organisational changes

A significant organisational trend, discussed in previous chapters, is the narrowed ownership structure of the grocery chains. This development essentially means that fewer hands control a larger share of the industry's turnover than was previously the case.

One direct organisational and technological outcome of this rise in the power of the grocery chains has been an increase in private branding. Private brands are exclusive product lines produced for, and sold by, grocery store chains, in place of established products and brands. Early examples of private branding were the blue-and-white products of the NKL / Co-op stores in the 1970s. Today, sales of private branded

Ringnes Gjelleråsen

After a rapid reorganisation of 23 breweries (mergers, take-overs and bankruptcies) the last decades, Ringnes is today one of the few remaining ones, and Norway's largest brewery with about 1.100 employees.

Process-technological developments the last decade has induced large changes in the production hall. Manual work, as cleaning, sorting, and to some degree lifting and loading, has been completely wiped out and exchanged with mechanical machines and lifters, advanced computerised storehouses and robot transporters. This has of course had influence on the labour stock. However, the labour union has - contrary to what one should expect - been active in the process of automation.

- We anticipated the technological development years ago, we knew that there were international breweries producing more efficient than us, says labour unionist Arne Rolijordet at Ringnes. - The initial problem was that we were almost disempowered. The workers at the brewery are foreign workers, with low formal skills and do often not speak Norwegian very well. So what to do in a situation of implementation and use of advanced equipment, threatening the jobs? We proposed to the management that we would be in favour of production technology change if - and only if - the employees were able to fully have the possibility to learn the new machines; our intention was that the employees should 'gain control over the production means'. And this has been a great success. We now have a broad array of certifications granted to almost all the machines, and maintenance and repairing is done by people working on the plant.

products represent around 7% of total turnover, an increase of 2% in two years⁴⁸. Organisationally, this has meant increased vertical integration between the grocery chains and some producers. Examples of companies producing private brands of beverages are Fontana (located at Stabekk) and Grans.

It is difficult to judge whether or not this increase in private branding will continue. So far, the share of the market taken up by private brand products is relatively low. It is, as Dulsrud⁴⁹ suggests, possible to anticipate an increase in downstream integration between food producers and their own suppliers as a counter to integration among the grocery stores, as has occurred in the dairy sector. Such trends are already discernable in meat production and poultry.⁵⁰

Science-based products and processes

One of the main international developments in the manufacture of food products in recent decades has been the shift away from so-called empirical principles towards scientific principles (Lindgaard-Christensen et al., p. 31). We have already made reference to this point, and illustrated it with empirical material in Chapter . Research and development, research environments, and external knowledge in general seem to be increasingly important to the innovation process in the food industry. There are over 30 research environments delivering intelligence to the food industry; R&D now takes up about 1/3 of innovation expenditures in the industry, and R&D institutes are often reported as being important knowledge providers to technological co-operation projects. It is apparent that other important inputs such as ingredients and machinery are increasingly dependent on research. Another discernable trend is the increased use of modern scientific machinery, for instance in the integration of ICT with traditional mechanical machinery (Pedersen, current work on doctoral thesis, STEP Group). At the Ringnes brewery at Gjelleråsen, much of the transport and storage of mineral water loads is performed by robots.

New ingredients

Research is playing a large role in the development of new ingredients. An illustrative example from Nøttefabrikken is the change from organic to synthetic oils in the process of roasting nuts (although the factory has been reluctant to implement this change). Lindgaard Christensen et al. categorise this as part of a general transition, one that they describe as "a substitution of 'natural' for 'artificial' ingredients such as emulsifiers, stabilisers, antioxidants etc."

Many of these artificial ingredients have generated collective anxiety, persuading manufacturers not to use them. A further trend has therefore been the search for - and the use of - so-called 'nature-identical' additives, natural additives that replace less resistant additives, such as strawberry flavouring which is harmed by even the slightest amount of processing.

⁴⁸ Dulsrud, A. *Markedstrender og utviklingen i distribusjonsmønsteret*, in Borch and Stræte 1999, op.cit.

⁴⁹ Ibid.

⁵⁰ Ibid p. 126

New products and trends among consumers

We have noted the increasing market-orientation of the food industry, and the fact that many strategic decisions are taken with reference to consumer trends. It is important to remember that this is in many ways a completely new development, as product development previously emanated technologically from existing production processes.

One major trend among consumers is the demand for safe food products. Increased concern over artificial ingredients, the BSE scandal, and the Belgian Coca-Cola mishap are just some of the powerful forces behind this development. Consumers' concern over food safety is one of the major reasons why branding is so important in food production, which in turn partly explains the reluctance in some parts of the industry to introduce new products. (Lindgaard Christensen et al. p. 31).

However, there have also been consumer-led changes on the product side. According to Lindgaard Christensen, the most significant of these have been:

Increased emphasis on prepared meals. A fall in 'free' time, with both men and women going out to work, has resulted in an increase in the consumption of prepared meals. The products of Fjordland Kjøkken is an example of this development in Norway. A sub-trend within this the surge in the popularity of ethnic food.

Increased consumption of snack food and 'casual' food. This development has varied in extent between countries, with the trend strongest in northern Europe and the USA.

Healthier food. Increasing numbers of the western population are concerned with the health implications of the food they eat. The extent of this concern varies considerably according to social strata, sex, geography, and age. (For example, one study has shown that Mediterranean women in their 40s are one of the groups most

Matforsk

Matforsk is a research institution located at Ås, with 150 employees whereof about 70 researchers. Matforsk performs research in almost every chain of food processing, including food safety, biotechnology, monitoring, electronic nose-technology, wrapping, quality analysis, chemometry, washing and cleaning of raw material and market research. The value of industrial financed research was doubled in the periode 1994-1997, from just below 15 million NOKS to almost 30 million NOKs. The institute has currently large product development projects with BAMA/Gartnerhallen, and a collection of Norwegian bakeries.

According to the market director at Matforsk, food research has for a long time been aimed at production of raw material, while the processing industry has been neglected. The institute is therefor, together with a handful persons in Norconserv, Fiskeriforsk and SINTEF taking measures towards the industry, by starting a 'one entrance' product development organisation to companies with research related needs.

Matforsk is the largest institution of its kind in Norway serving the food industry. The institute meet little competition from consultancies. According to the institute, consultancies will not survive for long time in this fields, as the technological development is so rapid. "Currently we are for example working with topics like gene technology, sensing and monitoring. These are all areas where development happens incredibly fast. Noone outside a research environments would be able to keep up with development".

affected by this desire for healthier food.)

Technology transfer and opportunities

As a starting point it is important to note that, in terms of technological diffusion and knowledge diffusion, the food industry represents one of the most well-organised production systems in Norway today. The bottom-up vertically integrated system of co-operatives stands as a good example of efficient knowledge diffusion⁵¹. The system is distinguished by groups of sub-suppliers gathered under commonly owned umbrella organisations, 'mother' entities with progressive market divisions and research laboratories, which actively acquire external knowledge such as research results, market intelligence and technological knowledge.

The system is also internationally integrated, with many Oslo-located companies foreign-owned. These are often local manufacturers and distributors for large groups such as Nestlé, and little product development takes place on a local level in these companies. In terms of technological co-operation, a substantial number of Oslo-based companies have connections to foreign partners or owner, as we showed in a previous Chapter. This method of technology transfer represents something of a double-edged sword for the region. On the one hand, these relationships put the Norwegian food industry in a better position to participate in international technological development. On the other hand, such patriarchal structures can lead to technological and economic dependency, with product and process development (and strategic decisions regarding the location of industrial activity) controlled from head offices outside the region.

Structural weaknesses exist within both the co-operatives and the foreign-owned subsidiary companies. Some companies suffer from low skill levels among their employees, some find the power of the grocery chains a difficult obstacle, and some have too little contact with research institutes. The essential problem facing the industry is: how can innovation activity in companies be increased, and what form should this innovation take?

The market director at Matforsk is attempting to increase the pro-activeness of the industry, arguing that companies that have no regular contact with research environments have an urgent need to improve this relationship. The problem is not always a financial one; some companies complain of a lack of time to spend on such activity, while others have more general mental barriers towards the research environment that are difficult to overcome. Matforsk regularly arranges technical courses on food, but few small companies have the time to participate. However, she also points out that when representatives from Matforsk make visits to food companies, the managers often pose questions about technical and scientific problems they need to solve. Matforsk has proposed special funding aimed at increasing pro-activeness among small and medium-sized businesses as part of their contribution to the next Stortingsmelding (parliamentary report) on agriculture.

For small companies, marketing, measurement of market trends and product testing are expensive undertakings. Marketing is often a company- and product-specific activity. However, measurement and interpretation of market trends and product

⁵¹ On the homepages of TINE, is it possible to participate in discussions on milk quality, production quotas, equipment, animal diseases, veterinary tips, etc.

testing are two areas in which small, independent food companies might benefit from developing synergies by acting together. According to interviews, there is currently no organisational body through which small food companies might engage in this kind of collaboration.

Another problem related to technology transfer opportunities is how companies go about coping with the increasing sophistication of products and production equipment. How can companies keep local or regional control of production while capital is becoming so globalised? The answer is by no means simple, but recent literature taking regional innovation systems as its point of departure has produced some suggestions, albeit long-term: as the technology becomes more and more advanced, it is important to continue to stimulate learning in all parts of the production process. In the case of Ringnes we saw how, as production became more automated and machinery more sophisticated, the labour union made a deliberate attempt to keep control of machinery by stimulating learning and running courses for their members. Increased production-related knowledge among workers - in this case knowledge of how to repair and maintain machinery - makes the production process more stable and reliable, but it also makes it more difficult for Ringnes to move their production out of the region, as new staff would have to be trained from scratch.

Economic activity is increasingly international; developments over the last decade in transport and communications technology have made it easier to relocate production, and to transport goods over longer distances. Technological developments in freezing and packaging have also facilitated the transport of food over greater distances. Although food remains essentially a 'fresh' product, with transport-time a limiting factor, transportation and freezing technologies are developing rapidly, and there is no doubt that, theoretically, these developments diminish the importance of location in terms of *distance to market*, while at the same time *a skilled work force is becoming increasingly important*. In other words, there is nothing to prevent the growth of the industry in the Oslo region as a producer of food for an international market. How can the industry internationalise in this way? There are several possible ways in which the Oslo region's food industry can pursue this strategy of internationalisation: i) through a strategy of vertical integration by acting as sub-suppliers to international Norwegian companies, as in the case of the Hakon/ICA Group, ii) through a strategy of co-operation or merger with international companies that have established international distribution systems, as in the case of Freia, and iii) through the building of a national giant with an aggressive international strategy, as in the case of ORKLA and to some extent TINE. In addition, we have seen that it can be attractive for international companies to establish local production facilities, as in the case of Nestlé or, more recently, the Coca-Cola plant.

Summary

We have briefly examined organisational and technological trends in the food industry. We have looked at the increasing complexity of innovation, along with organisational changes, increasing 'scientific' influences on production, new ingredients, and new products and trends.

We have also analysed technology transfer and opportunities, and highlighted three ways in which innovation might be stimulated in small food companies. These are: i) increasing pro-activity from the research environments, ii) encouraging collusion

among small companies in market intelligence gathering and analysis, and iii) internationalisation through vertical integration with retail chains. The next section will summarise the conclusions to be drawn from this chapter and its predecessors.

6. Summary

Introduction

This paper has attempted to present a broad overview of the dynamics of the food industry in the Oslo region⁵². More concretely, the key aim of this paper was to analyse the innovation performance of the industry, highlighting possible knowledge gaps and suggesting policy measures which will improve the performance of the system.

Innovation - possibilities and limits

We have pointed to the fact that food is a major industry - food companies in the Oslo region employ about 7,500 people, equating to approximately 14% of national employment in the food industry. The industry's main activities in the region are beverage production and the production of pastry/miscellaneous products; these employ a total of 4,250 employees, representing almost 65% of the region's food employment. Most of this employment is found in larger companies with over 200 employees.

We have seen that the Oslo region is of particular importance from a national perspective: most of the knowledge providers – providers of food-specific knowledge, technological knowledge and market knowledge - are located in Oslo. In terms of technological diffusion and knowledge diffusion, the food industry is one of the most well-organised production systems in Norway today. The vertically integrated bottom-up system of co-operatives stands as a good example of efficient knowledge diffusion, at least among the members of the co-operatives. The system is distinguished by groups of sub-suppliers gathered under commonly owned umbrella organisations, 'mother' entities with progressive market divisions and research laboratories, which actively acquire such external knowledge as research results, market intelligence and technological knowledge. In this respect the Oslo region is important from a national perspective, as many of the food co-operatives' head offices are located in the region, working as knowledge and technology providers, diffusers and co-ordinators for a wide range of producers throughout the country.

In terms of technological capability, several interesting patterns have been noted. Oslo-based companies tend to be more international in their outlook than other food companies in Norway. For example, they co-operate more often with foreign research institutes. They co-operate more frequently with research environments in general, and use these environments as inputs to their innovation activities. Also, more than companies in the rest of the country, Oslo-based companies tend to

⁵² E.g. the counties Oslo and Akershus

appreciate the importance of fairs, exhibitions and conferences as sources of information on innovation.

Employees in the Oslo region are more ‘trained for training’ than food processing employees in the rest of Norway. They are, in general, slightly better educated than their counterparts in the rest of the country. Food companies in the Oslo region more often have employees who are educated in sales, marketing, and accounting, although their proportion of technically educated staff is the same as national average for food companies.

Compared with other industries, the level of formal skills and qualifications among food employees is generally low. Although food companies in the Oslo region have more formally skilled employees than the national average for the industry, the level is quite low compared to other industries in the region, and compared to the generally high levels of formal skills among Oslo workers.

A global trend in the food industry is the ‘scientification’ of production. In Norway, this manifests itself in over 30 research environments serving food-related areas, encompassing both marine products and agrofood products. A disadvantage of this development is that it moves product development away from the factory floor and into the research department. Hence, employees’ practical contact with - and understanding of - the product and the production process is in danger of dissolving. This in turn could lead to decreasing innovative input from people who have a direct relationship to the day-to-day production process.

A final factor which may hamper innovation is the grocery chain oligopoly. When asked what they considered the main hindrance to innovation in their industry, many companies cited the power of the food retail chains. Companies complain of the difficulty of getting new products onto the shelves, the difficulty of developing long-term and stable relationships with the chains, and the retailers’ increasingly overwhelming preoccupation with price cutting; they argue that these obstacles can make it unattractive for food processing companies to develop new products. Although there are some positive aspects to the retail oligopoly (see pp. 92), it is clear that as long as the chains retain such power, they will be seen as a hindrance to new products and new entrants to the food industry.

Is there a knowledge gap in the region?

In this analysis we divide ‘food knowledge’ into three broad categories; food-specific knowledge, technological knowledge and market knowledge. Food-specific knowledge includes knowledge about selection and preparation of raw materials, processing, preservation and storing, nutrition and quality, n&c documentation and hygiene, safety, and cleaning. Technological knowledge includes knowledge related to packaging, wrapping and coating, transport, and logistics. Market knowledge includes knowledge of trading, sales, marketing, branding, and market/consumption trends.

We have already highlighted several knowledge gaps that exist in the region. Most of these gaps are found in the area between scientific research on the one hand and implementation and use on the other. We will summarise these gaps briefly before presenting them more systematically. Table 7 gives a brief overview of the different knowledge areas in food processing, together with a comment on the regional

industry's performance in this area, the technology gaps discovered, and suggested solutions. Based on interviews and statistical analysis, this overview in Table 7 highlights three outstanding problem areas for the food industry in the Oslo region:

- i) **Research barrier:** Research institutions can be expensive for small companies to use. There is often a mental or cultural barrier between companies and research environments. According to interviews, small companies have little experience of contact with research institutions, lacking the necessary time to devote to such contact. As a result, they often have no clearly articulated problem areas.
- ii) **Profile:** Food research environments in the Oslo region are poorly adapted to local food industry's activities. Most research is centred on raw materials handling, while the bulk of the region's actual industrial activity is in beverages and pastry/miscellaneous products.
- iii) **Market entry for new products:** It can be very difficult to launch new products into the market, as retail chains are overly concerned with large volume and low prices.

Where should RITTS intervene directly or indirectly?

According to the interviews conducted in the industry, many companies face a day-to-day struggle to stay afloat. However, it is important to recognise that many of their problems are the result of structural phenomena not directly related to the issues with which the RITTS programme is concerned. The interviews give the impression that companies generally regard technological innovation as an internal company process, for which they do not expect support from public policy.

The most ubiquitous and pressing problem raised by the interviewed companies has been the organisational structure of the retail chains, to which many companies find it difficult to adapt. Some report that new products are difficult to introduce under the existing chain system, claiming that if a supplier wishes to introduce a new product, another product from that supplier must be taken off the shelves. For the smallest suppliers it is virtually impossible to break into the retail chains, as many of the chains demand large quantities of each product in order to distribute a standardised national product spectrum to all the shops in their chain. Large companies face competition for their products from private branding, and some are forced to turn to manufacturing private brands themselves in order to maintain production levels. For the smaller companies, price and volume are the key factors which make it difficult to enter these narrow distribution systems.

It is also important to recognise that the food industry in many ways is managing reasonably well by itself. Technologically, the Oslo food industry is well-endowed, with an array of national and regional research environments such as the Ås complex and UiO, machinery suppliers, and a broad range of market research providers in the region. The close proximity of these knowledge providers is an important asset to the region's food processing industry. The Oslo-based food companies, to a much greater extent than provincial food companies, make use of universities and research institutes as knowledge providers for their innovation activities. In addition, many companies are under the umbrella of a co-operative system, through which external knowledge and research is purchased collectively and distributed throughout the co-operative. Many of these co-operatives have their headquarters and research divisions in the Oslo-region.

In Table 7 we have presented some indicators as to the performance of the regional knowledge and innovation systems in the Oslo food processing industry. From this we have made some suggestions for policy intervention.

Food is an industry which experiences rapid technological change, but in which smaller companies have relatively little capacity to absorb this development. This is partly due to low formal skill levels, and partly due to a lack of time to spend on innovation activities. The first policy proposal is to stimulate the active use of researchers in food production; to keep a running contact between industry and research, with particular focus on the needs of small and medium-sized companies. One practical measure might be the establishment of one or two full-time research positions whose main function would be to visit and advise small companies in the Oslo region on a proactive basis.

Market intelligence and trend monitoring are increasingly important to food production, but small companies often find themselves economically hindered from acquiring such knowledge. One solution to this might be to encourage independent companies to join a common organisation, whose object would be the discussion of common needs and demands, with particular focus on trend patterns, test panels, interpretation and analysis of social developments (for instance, the ways in which an increased proportion of elderly people in the population should affect product portfolios). Members would have only their size in common, and the more heterogeneous the companies in such an organisation were, the better it might perform; discussion of industry-specific 'secrets' could be avoided.

Small and independent companies often feel that they have little power relative to the four large food distributors. The development of such an organisational body could be one way to increase their negotiating power and facilitate the distribution of quality products that are attractive to consumers in the region.

Much food-related research has traditionally focussed on the production of raw materials. In order to stimulate innovation and the use of scientific research in the food processing industry, it is important to acknowledge that knowledge means more than just knowledge of raw materials; it also includes technological and market-oriented knowledge. It is important for the industry that research institutions move closer to the actual structure of the food-industry in the Oslo region in their research activities. According to interviews conducted in the food-research institutions, these measures are already being implemented. However, at the same time these institutions are required to look further than the Oslo region, and some of them point to the potential of other national industries, in particular the major industry of fish processing.

Table 7: Knowledge areas in the food industry and regional performance

	<i>Performance in the Oslo region</i>	<i>Gaps</i>	<i>Solutions</i>
Food-related knowledge (selection and preparation of raw materials, processing, preservation and storing, nutrition and quality, n&c documentation and hygiene, safety and cleaning)	Broad array of advanced research institutions serving this field. Most are located in the Oslo region. Companies in Oslo are more frequent users of this scientific knowledge than other food companies in Norway.	Many of the institutions are private, and can be expensive for small companies to use. There is often a mental barrier between companies and research environments. According to interviews, small companies have little experience of research contact, no articulated problem areas, and little time to spend with research institutes.	A more proactive approach from the research institutions towards the SMEs
Technological knowledge (packing, wrapping and coating, transport and logistics)	The bottom-up co-operative structure of large parts of the industry works as a well-organised way of distributing knowledge and innovation. The 'mother' entity acquires research and market knowledge (ref.), and diffuses this throughout the production system. Many of the head offices are located in Oslo, and they have strong relationships with the research environments in the region. Technological machinery is usually imported, and there are few local suppliers of machinery (most common are foreign machinery suppliers with local agents). Companies in the Oslo region seem to be more dynamically integrated with suppliers. Many of them have reported direct technological co-operation with foreign suppliers of machinery. Companies in the Oslo region have a slightly higher proportion of skilled employees than food companies in the rest of the country. This may mean that these employees are more 'trained for training' than others in the national food industry.	Research institutes have traditionally been preoccupied with research on raw materials, and paid too little attention to the needs of the processing industry and to market trends. It is noteworthy that although production of beverages is one of the main activities in the Oslo region food industry, few research environments supply the industry with research in this area. Increased scientification of both production equipment and food processing make it necessary for companies to develop more stable relationships towards research environments in order to keep up with developments.	Adapt technological profile of research institutes towards the actual structure of the regional industry. A more proactive approach from the research environment
Market knowledge (trading, marketing, sales, branding, distribution, market and consumption trends)	Food companies have been increasingly consumer-oriented in recent years. Market knowledge is of increasing importance to food companies. Market research costs as a percentage of innovation costs are much higher than in other Norwegian industries. Food companies in Oslo have a higher proportion of employees with formal market/economic skills than provincial companies. Despite this, market knowledge is often acquired from external suppliers. Most providers of this knowledge-category are located in the Oslo region (BI, NMH, Matforsk, NILF, ACNielsen, etc.).	These services are relatively expensive. Market knowledge is therefore more often systematically acquired or purchased by larger companies. Formalised marketing and product development departments in these companies also indicate a possible underperformance by small companies in these areas. There is currently no organisational body through which smaller companies can acquire market or distribution services collectively.	Developing a horizontal organization among small food companies to I) increase usage and diffusion of market monitoring and II) develop a common strategy towards the chains is a possible solution

Summary

We have shown that the food industry in Oslo is an important part of the full industrial picture in the region. The food industry uses complex knowledge bases as sources of innovation; the region's employees are more formally skilled than their counterparts in the rest of the country; the industry has tight relationships with

foreign research environments and foreign suppliers of machinery; and companies in the region have a large pool of market research institutions on their doorstep, the use of which are increasingly important to the industry.

We have highlighted the significant differences in the ways in which small and large companies innovate. Large companies are better adapted - both organisationally, and in terms of production volume - to serve the national retail chains than the smaller companies are. Large companies also have the economic power to promote brands, finance launch campaigns for new products, and undertake research and product development. However, small food companies finance comparably large shares of total R&D.

The potential for small companies to succeed within this structure might seem slight. However, there are a number of options available to them, some of which are industry-dependant. Some of the key issues are organisational, the core problem for many companies being how to enter into and maintain stable relationships with the grocery chains. For some, such as Fontana, private branding has been the solution. Others, such as Den Lille Nøttefabrikken, have stayed away from the major grocery chains, targeting gas stations and kiosks/newsagents, while Majonæsfabrikken and others have targeted local branches of the chains with the largest product ranges.

It seems likely that the concentrated ownership structure in food retail will remain dominant for the foreseeable future, and that it will be difficult for small companies to operate outside of the main chains. We have already suggested some horizontal integration among small food companies in order to match the chains through a strategy of regional collaboration. Relations with the retail chains may even increase in importance: if the trend of internationalisation seen among Norwegian retail chains in recent years continues to progress, Oslo-based companies that are vertically related to one of these chains will potentially enjoy the additional benefit of increased access to foreign markets.

Appendix 1:

Interviewed persons/companies/location/date

We are grateful to the following people, who kindly contributed invaluable insights and information to this report:

- Rector Roger Abrahamsen, Norges Landbrukshøgskole, Ås, June 22., 1999
- Head of Research Colin Murphy, Norges Landbrukshøgskole, Ås, June 22., 1999
- Director Kjell Aksnes, Norges Landbrukshøgskole, Ås, June 22., 1999
- Market director Finn Messel, Den lille Nøttefabrikken, Hauketo, July 6., 1999
- Manager Pål Glatz, Majonæsfabrikken, Majorstua, July 7., 1999
- Market Director Stein Drogseth, TINE Norske Meierier, Grønland, July 16., 1999
- Division Director Lars Espen Aukrust, Bio-production and Processing Division (Bioproduksjon og Foredling), Norwegian Research Council, Sept. 16., 1999
- Market Director Gabriella Dånmark, MATFORSK, Ås, Sept. 20., 1999
- Labour Unionist Arve Rolijordet, Ringnes AS, Gjelleråsen, Sept. 21., 1999
- Trade Marketing Manager (retail) Karl Bønnehof, A/S Nestlé Norge, Billingstadssletta, Sept. 22., 1999

Appendix 2: List of Case illustrations

Company	The case illustrates...
Majonæsfabrikken	<i>Informal innovation process in small companies, Product specialisation and quality focus in small companies Food products are easy to copy, Small companies' relation to distr./ detail chains</i>
AS Nestlé Norge	<i>Internationalisation of product development Advantages of being a trans-national company subsidiary ... and disadvantages The role of knowledge development</i>
Den lille Nøttefabrikken	<i>Product specialisation and quality focus in small companies The role of market approach and design in food companies The role of external knowledge (design, traders, machinery)</i>
TINE norske meierier	<i>The increasing complexity of innovation activities The role of external market knowledge in innovation The role of internal research activity in large co-operatives</i>
Ringnes Gjelleråsen	<i>Local learning as competitive advantage The automation process in the industry The dominance of unskilled workers in the industry</i>
Matforsk	<i>The historical emphasis on raw materials research Reorganisation of research activities to meet ind. demands The marginal role of consulting in food processing</i>

Part III: Innovation patterns, knowledge bases and cluster formations in electronic and electrotechnical industries in the Oslo Region.

By Finn Ørstavik

Main findings:

- Oslo is clearly the dominating in the Oslo and Akershus area in terms of presence of “technology firms” and employment in these firms,: When we distinguish between the North, East, South, West area of Akershus, and the municipality of Oslo, we find that more than half of the firms (58%), and almost 2/3 of employment (58%) in Oslo.
- ICT services firms make up 60% of “technology companies” in the region, while employment is 58% of total employment of this group of companies.
- Oslo:
 - Dominating with respect to technology industry in the region
 - The machinery group of firms is dominated by Kværner Energy, otherwise few and small companies
 - Few firms in electronics, but Tandberg Data is large, and also other large firms have significant electronics activities.
 - Weak electrotechnical group, Alcatel Kabel, Electrovakuum and Siemens are the biggest
 - Vehicles, railways and leisure boats group is small in number of firms, dominated by Oslo Sporveier and NSB
 - Offshore and shipbuilding is insignificant (in terms of production firms)
 - ICT is very important, many firms, a substantial number with significant employment. Also many small firms.
- Akershus North
 - Weak position in the region with respect to technology industry
 - Dominating electrotechnical group. Several firms at Årnes/Bøn: Electrolux electric cookers production, cable production, electrical accessories
 - Important changes after 1996, as the new Oslo Airport was built at Gardermoen.
- Akershus East
 - Modest position with respect to technology industry
 - Machinery group represented with firms such as Kværner Energy, Selmer and Bakelittfabrikken

- Four electronics firms with more than 10 employees
- Some significant firms in the electrotechnical group, such as Norwesco
- Vehicles, railways and leisure boats group is appears quite strong, with AD Tranz dominating
- Offshore and shipbuilding is represented by Norweld
- ICT is insignificant
- Akershus south
 - Weak except in machinery and ICT
 - Machinery group cluster around Ski.
 - Two small firms in electronics
 - Electrotechnical group represented by Alcatel Kabel and Eldrive
 - Vehicles, railways and leisure boats and Offshore and shipbuilding groups insignificant
 - ICT is dominated by IBM, and there is one other significant firm which is located in the IBM buildings in Oppegård
- Akershus West
 - Strong position with respect to technology industry
 - Machinery group represented by Tomra Systems
 - The strong electronics segment includes firms such as Nera, Ericsson, and Tandberg.
 - Several electrotechnical firms, among them Elektrokontakt and and ABB
 - Vehicles, railways and leisure boats group is significant because of airline companies such as SAS and Braathens (Moved since 1996)
 - Offshore and shipbuilding is absent (in terms of production firms)
 - ICT is very important, many firms, most small or medium sized.
- Firm sizes: Very many very small firms
 - All areas have high shares of small firms
 - (About 2/3 of firms have between 1 and 5 employees)
 - Oslo and Akershus West have the lowest proportion of small firms and the highest share of large firms (100+ employees)
 - The highest share of firms with 1-5 employees are in ICT, but
 - The different industry groups are quite similar with respect to firm size distributions
- All large firms are innovative
- The motivation for innovation efforts:
 - Electronics firms are concerned the most with replacing existing products, extending product range, extending markets and improving market shares

- Electrotechnical firms are concerned with cost cutting, but are even more interested in improving product quality, extending product ranges. The most interest is attached to replacing existing products.
- The innovation system in electronics is globalised
- The innovation system in the electrotechnical field has traditionally been a mix of home-market oriented and dominated by large international firms, but is increasingly becoming more globalised.
- Case analysis shows that firms have different approaches to business development and innovation:
 - Some choose a quasi-autonomous technology strategy where a significant effort is done to lead development in a technological area.
 - Several firms attempt to live in the protective shadow of a larger firm, supplying products that “fill in” the large firms product range, often taking care of specific needs in the Norwegian market. This we call the complementary technology strategy
 - A niche technology strategy is found in many firms which resembles the quasi-autonomous strategy, but is more modest with respect to competitive leadership and growth.
 - Finally, we can distinguish an empire building strategy which can be driven by organisation building ambitions, or by an economic logic which aims at accruing economic gains by institutional and economic restructuring of existing industrial activities. In both versions, the strategy tends to aim at globalisation of operations.
- Policy issues:
 - Public knowledge infrastructure does not appear to play an important role because of proximity in itself: Cultural distance and competence mismatch cannot be compensated by co-location.
 - For electronics firms, leading competence may be found in the US, and the cultural divides do not appear to represent serious problems. In this case, the geographical distance, time differences and travel costs, however, do represent significant obstacles.
 - Public knowledge infrastructure institutions are important for existing firms when young people are given skills and competence that are relevant for these firms. The matching of education and business needs appears to be a big problem in the Oslo and Akershus region.
 - Firms apparently do not find that neither institutions in higher education nor non-profit research institutes are easy to access or easy to build profitable partnerships with.

- Small firms find it very hard to orient themselves in what is going on in public institutions, and in what way public institutions are doing efforts that are intended to be helpful for them
- Small firms find the cultural divide between themselves and researchers in institutes and universities is an insurmountable barrier to constructive collaboration. One aspect of this is that researchers tend not to understand how important specific research objectives are for the future of the firm, and how important it is to keep within the project budget and time-constraints that are a sine-qua-non for the survival of firms.
- Larger firms find it easier to access researchers in public knowledge infrastructure institutions, and they are more able to locate competent people who are suited for participating in collaborations. Still, also larger firms voice some of the same concerns as the small firms do.
- The university is considered a very difficult partner for industrial firms, also large ones, because the university administratively functions as a slow moving, and at times incomprehensible, bureaucracy. ("Lack of professionalism.")
- State of the art research which is not directly related to ongoing business operations can still prove a source of industrial growth, by way of spin-off of entrepreneurial firms. The precondition is that researchers themselves are interested in the potential of bringing their knowledge and competence over into commercial operations.
- In general, there appears to be a low level of interest in business and new business ventures in university and research institutes in the region. The existence of a venture capital market which make the profit opportunities bigger and more visible may promote a gradual change in this area, but one should not underestimate the cultural inertia in this area.

1. Introduction

In this and the following part of the report focus is set on what the RITTS Oslo Project Group has defined as the *Technology Firms* in the Oslo and Akershus region. That is, we analyse companies in the following industries:

- Machinery and machine tools (in part 4)
- Electronics, computers, instruments and industrial automation
- Electro-technical
- Vehicles, railway, aircraft and leisure and sporting boats
- Offshore and shipbuilding

This broadly corresponds to the industries covered by the categories 29, 30, 31, 32, 33, 34 and 35 in the NACE classification scheme.

In addition we have included

- Information and communication technology services

(NACE class 72) into the introductory statistical analysis.

The Machinery and machine tools industry is dealt with by Heidi W. Aslesen in part 4, and will not be analysed further here.

Statistical classifications do not give immediate grasp of the structure and functioning of any industry, but statistics may nevertheless offer valuable insights – especially when combined with other analyses of structures and functions. We therefore commence the analysis in this report with a simple statistical overview of the industries we are interested in. This is section 2. Thereafter, in section 3, we present some results from the Community Innovation Survey 1997, which offers insights with respect to innovation patterns in the industries we focus on here. (Our focus in section 3 is mainly on the electronics and electrotechnical industries.)

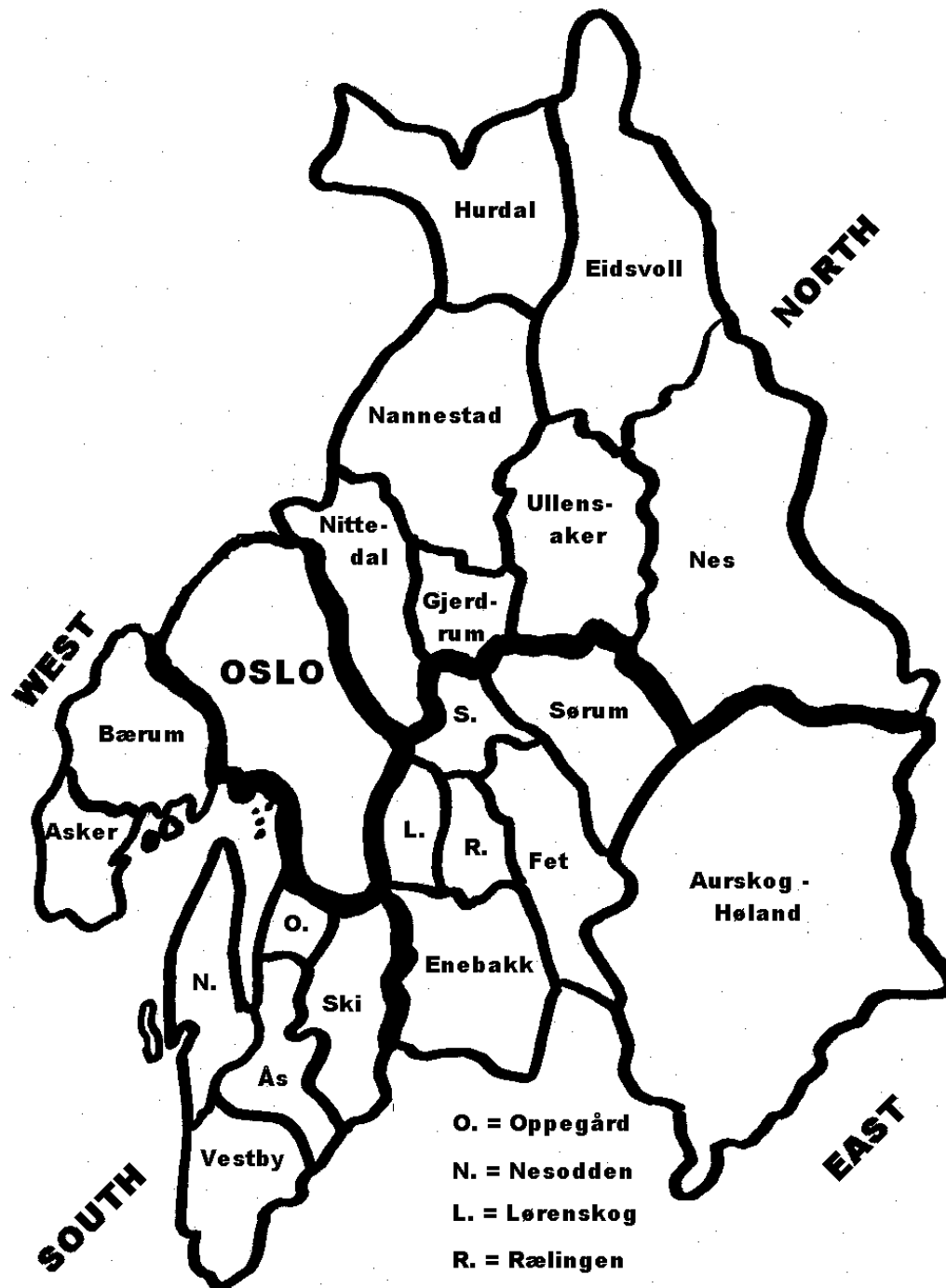
On the basis of these exercises and of further qualitative inquiries that we have undertaken, we in sections 4 and 5 develop a broader analysis of the electronics and the electrotechnical industries, and the innovation patterns that are observed in the industries.

2. The “technology industries” in the Oslo and Akershus region

In the tables below we have divided the Oslo and Akershus region into 5 different geographical areas. These are defined in the following way: “North” is the municipalities Nittedal, Nannestad, Hurdal, Eidsvoll, Nes, Ullensaker and Gjerdrum. “East” is Aurskog-Høland, Sørum, Fet, Rælingen, Enebakk, Lørenskog and Skedsmo. “South” is Vestby, Ski, Ås, Frogner, Nesodden and Oppegård. Finally, “West” is Asker and Bærum.

This is illustrated in the figure below.

Figure 1: The Oslo and Akershus region



The industrial sectors we consider are those covered by NACE 29-35 and 72. We have made a simple classification where we distinguish between the following main sectors: Machinery and machine tools industry, the electronics, data, instruments and industrial automation equipment industry, the electrotechnical industry, the vehicles, railway, aircraft and leisure and sporting boats industry, the offshore and

shipbuilding industry, and finally the information and communication technology services industry. (See appendix 1 for a detailed explanation of what NACE categories are included into our categorization.)

With this starting point we will discuss briefly where industries are located, how many firms there are, the size of firms, etc. We base our analysis on public register data from 1996, which were the newest we had access to during the work with this report.

First, let us consider the geographical location of different industries. Table 1 shows the number of firms for the different industries in the areas we have defined.

Table 1a: Companies by geographical areas. Number of firms. (Absolute.)

	<i>North</i>	<i>East</i>	<i>South</i>	<i>West</i>	<i>Oslo</i>	<i>All</i>
Machinery, machine tools	19	28	21	12	79	159
Electronics, computers, instruments, automation	2	10	4	17	25	58
Electro-technical	11	20	10	19	47	107
Vehicles, railway, aircraft, small boats	6	9	7	12	14	48
Offshore, shipbuilding	0	1	2	8	11	22
ICT-Services	14	28	27	123	396	588
Total	52	96	71	191	572	982

Table 1b: Companies by geographical areas. Number of firms. (Percent.)

	<i>North</i>	<i>East</i>	<i>South</i>	<i>West</i>	<i>Oslo</i>	<i>All</i>
Machinery, machine tools	37	29	30	6	14	16
Electronics, computers, instruments, automation	4	10	6	9	4	6
Electro-technical	21	21	14	10	8	11
Vehicles, railway, aircraft, small boats	12	9	10	6	2	5
Offshore, shipbuilding	0	1	3	4	2	2
ICT-Services	27	29	38	64	69	60
Total	100	100	100	100	100	100

The subsequent tables shows the distribution of employees by the same areas.

Table 2a: Companies by geographical areas. Number of employees. (Absolute.)

	<i>North</i>	<i>East</i>	<i>South</i>	<i>West</i>	<i>Oslo</i>	<i>All</i>
Machinery, machine tools	126	439	237	268	1584	2654
Electronics, computers, instruments, automation	8	140	27	1237	1430	2842
Electro-technical	481	218	198	267	699	1863
Vehicles, railway, aircraft, small boats	32	380	39	1016	1552	3019
Offshore, ships	0	82	5	27	208	322
ICT-Services	43	86	556	1218	7598	9501
Total	690	1345	1062	4033	13071	20201

Table 2b: Companies by geographical areas. Number of employees. (Percent.)

	<i>North</i>	<i>East</i>	<i>South</i>	<i>West</i>	<i>Oslo</i>	<i>All</i>
Machinery, machine tools	18	33	22	7	12	13
Electronics, computers, instruments, automation	1	10	3	31	11	14
Electro-technical	70	16	19	7	5	9
Vehicles, railway, aircraft, small boats	5	28	4	25	12	15
Offshore, ships	0	6	0	1	2	2
ICT-Services	6	6	52	30	58	47
Total	100	100	100	100	100	100

Oslo dominates in terms of number of firms as well as in terms of employment. Also in the West area, in Asker and Bærum, the population of technology firms and the employment in these industries are significant. The North, East and South areas have much less of the industry that we analyse here, both in terms of number of companies and in terms of employment.

In the two figures below we show the same distributions in relative terms. Combining this figure with information of single firms as reported in appendix 3, we are in a position to briefly characterise main features of the technology industry presence in the different areas.

Figure 2: Share of firms by industry category and geographical area

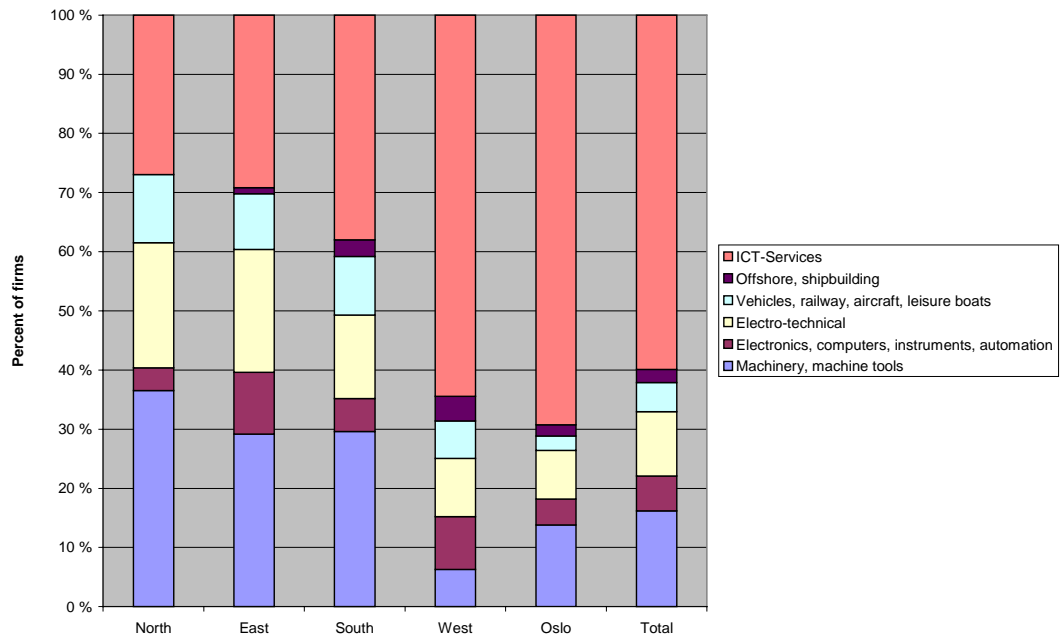
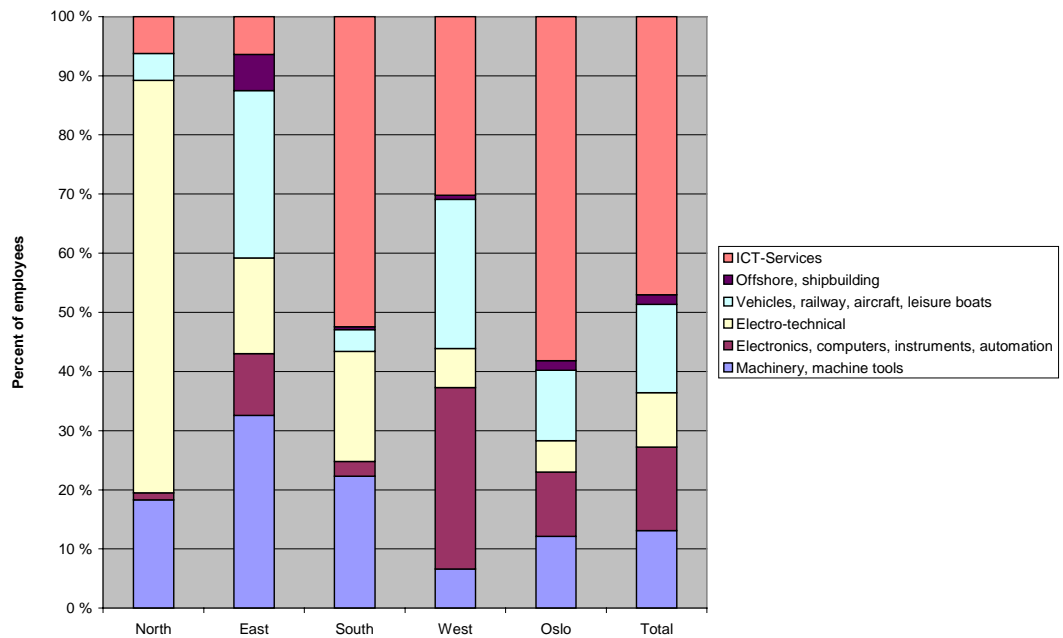


Figure 3: Share of employees by industry category and geographical area



Oslo is dominating in the region, both in terms of the number of “technology firms” located here, and in terms of share of employment in the industries we are analysing. The machinery and machine tools industry is composed of mainly small firms, but

Kværner Energy (with close to 700 employees in 1996) masks this fact, so that the share of firms and share of employees both are only modestly higher than 10%. There are only few firms in the Electronics segment, but Tandberg Data, Siemens and ABB Industri are relatively large firms, with altogether around 1000 employees (1996). The electrotechnical segment is rather weak in Oslo, the biggest firms are Alcatel Kabel, Electrovakuum and Siemens (with 164, 101, and 100 employees in 1996). The Vehicles, railways and leisure boats group is small in number of firms, and totally dominated in terms of employment by the Norwegian State Railways (about 1000 employees) and Oslo Sporveier (about half as many employees). In offshore and shipbuilding there are only very few firms, Aker Elektro is the biggest, with about 100 employees.

The technology industry group (among those that are included in the present analysis) is that is the most important in Oslo is clearly ICT services. There are many firms, a number of small and medium sized, and a notable number also of relatively large firms. The biggest among them are Alcatel (664 employees in 1996) Fellesdata (579) Bankenes Betalingssentral (571) and Andersen consulting (379).

The North area of Akershus has the least of the types of the technology industries that we are looking for in this analysis. There are a few firms in the machinery and machine tools sector with some employment, and there are a few small ICT services firms. The main employment is in the electrotechnical field, where there are a few relatively large firms. All these firms are located in Årnes. They produce household appliances and cable production. (See appendix 3.)

Akershus East has a modest number of firms and modest employment in the industries we consider here, compared to its neighbouring areas. (See tables 1 and 2.) In machinery and machine tools, the biggest firms are Kværner Energy (192 employees in 1996), Selmer (86) and Bakelittfabrikken (41). There are 4 firms with more than 10 employees in the electronics segment: Ecotron (61), Norteam electronics (24), Electrocompaniet (20) and Tandberg Educational (12). In the electrotechnical field, we find that Norwesco (67), Imek (47) and Norsk Elektronikk Service (22) are the largest.

ABB Daimler Benz transportation is the dominating firm in the Vehicles, railway, aircraft and leisure and sporting boats category. The firm had 253 employees in 1996. The three next firms on the employment ranking are Mopro (50) which makes steel tanks for large trucks, Handicapustyr (22) and Handi Norge (19).

There is one firm only in the offshore and shipbuilding industry: Norweld, with 82 employees.

The Information and communication technology services is small in this area; only two firms have more than 5 employees in 1996: Electronic data systems (28) and Microway (14).

Akershus South has quite a few firms in the machinery and machine tools segment as well as in Information and communication technology services. Almost all the firms in the former group are located in Ski, while the two big firms in the latter group are located in Oppegård, where IBM Norway has its main operations. (IBM having about 400 employees, 3part AS 57, in 1996). There are only two significant firms in the electronics segment, both of these are also found in the municipality of Oppegård.

In the electrotechnical industries, Alcatel Kabel is the biggest (98 employees) and is located in Ski, while the second biggest is Eldrive AS (67 employees) in Vestby.

The West area of Akershus is a geographically small, but densely populated area which is quite big in terms of technology industry (in the sense of this phrase that we employ here). In the machinery and machine tools segment, Tomra Systems in Asker is in a class of its own with its innovative products and 186 employees. The second largest firm, also located in Asker, is Flebu-Ticon, with 60 employees.

The West area also has a significant electronics industry. Nera (574 employees in 1996), Ericsson (508) and Tandberg Television (47) are the biggest companies.

In the electrotechnical segment the largest firms are Elektrokontakt (121), ABB (50) and Elplex (27).

The vehicles, railway, aircraft and leisure boats group count 12 firms, of which half are small marine service shops, while the airways companies SAS (793) and Braathens (67) dominate with respect to employment. The health and handicap equipment company Handicare AS in Asker seems to be the only manufacturing firm in this segment (49 employees).

Finally, **ICT services** make up a significant part of the firms in the technology industries in Akershus West. There are many firms, most of which are small or medium sized. 27 firms have more than 10 employees in 1996, 5 have more than 50. These are Oracle Norge (207), IFS Norge (87), Kongsberg Informasjonskontroll (70), Computas (67) and Intentia Norge (also 67).

Firm sizes by location and by industry

In general, there is a very high proportion of small firms. This is shown in table 3 below. The number of firms with up to 5 employees make up around 2/3 of the total technology firm population in Oslo and Akershus. Oslo and Akershus West have the lowest fraction of very small firms, and the highest proportion of large firms (100+ employees).

Table 3: Firm size (employees) by geographical area. 1996.

	North		East		South		West		Oslo		N	Total %
	n	%	n	%	n	%	n	%	n	%		
1	16	30,8 %	28	29,2 %	21	29,6 %	52	27,2 %	153	26,7 %	270	27,5 %
2-5	20	38,5 %	34	35,4 %	29	40,8 %	68	35,6 %	205	35,8 %	356	36,3 %
6-9	5	9,6 %	8	8,3 %	2	2,8 %	22	11,5 %	61	10,7 %	98	10,0 %
10-19	5	9,6 %	11	11,5 %	9	12,7 %	21	11,0 %	69	12,1 %	115	11,7 %
20-49	4	7,7 %	8	8,3 %	3	4,2 %	15	7,9 %	34	5,9 %	64	6,5 %
50-99			5	5,2 %	5	7,0 %	7	3,7 %	19	3,3 %	36	3,7 %
100-249	2	3,8 %	1	1,0 %	1	1,4 %	3	1,6 %	16	2,8 %	23	2,3 %
250-			1	1,0 %	1	1,4 %	3	1,6 %	15	2,6 %	20	2,0 %
Total	52	100 %	96	100 %	71	100 %	191	100 %	572	100 %	982	100 %

When we consider the different industry groups (table 4) below) we see that they are quite similar with respect to firm sizes. The highest proportion of one-man firms is in information and communication technology services (almost 1/3 of the firms), the

lowest share of such firms are found in the vehicles, railway, aircraft and leisure and sporting boats segment (12%), which also has the highest proportion of large firms (12% of firms have 100 or more employees). There are no firms with this many employees in the offshore and shipbuilding category in Oslo or Akershus, while the share of firms of this size is only 3,1% in machinery and machine tools, and 3,5% in information and communication technology services.

Table 4: Firm size (employees) by industry. 1996.

	Machinery, machine tools		Electronics, computers, instruments, automation		Electro- technical		Vehicles, railway, aircraft, leisure boats		Offshore, shipbuilding		ICT-Services		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	N	%
1	42	26,4	10	17,2	25	23,4	6	12,0	4	18,2	183	31,1	270	27,5
2-5	62	39,0	18	31,0	42	39,3	15	31,0	11	50,0	208	35,4	356	36,3
6-9	21	13,2	5	8,6	7	6,5	5	10,0	3	13,6	57	9,7	98	10,0
10-19	16	10,1	10	17,2	12	11,2	9	18,0	1	4,5	67	11,4	115	11,7
20-49	6	3,8	6	10,3	10	9,3	5	10,0			37	6,3	64	6,5
50-99	7	4,4	4	6,9	5	4,7	2	4,0	3	13,6	15	2,6	36	3,7
100-249	4	2,5			6	5,6	1	2,0			12	2,0	23	2,3
250-	1	0,6	5	8,6			5	10,0			9	1,5	20	2,0
	159	100	58	100	107	100	48	100	22	100	588	100	982	100

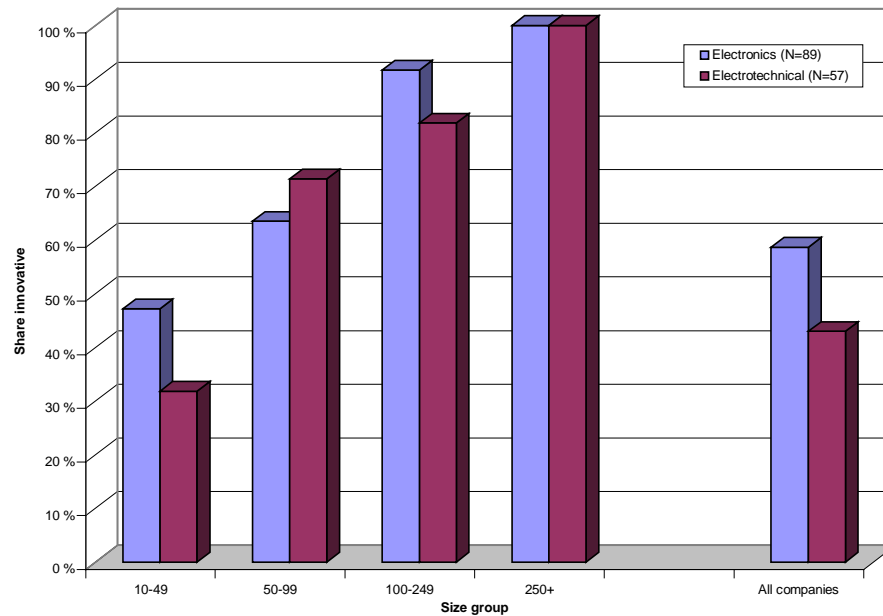
3. Innovation statistics for electronics and electrotechnical firms

How innovative are the firms in the electronics and the electrotechnical industries, and how do they innovate? We have looked into Community Innovation Survey data from 1997 in order to find some general statistical answers to these questions. The number of observations of firms from the Oslo region are too small to make a proper regional breakdown feasible. We therefore limit our analysis to point out some general features of these industries in Norway.

3.1. How many firms are innovative?

In the Community innovation survey 1997 manufacturing firms were asked if they had, during the period 1995-97, (i) introduced technologically new or improved products and/or processes. In addition, they were asked if they during the period 1995-97 had (ii) undertaken activity to develop or introduce technologically new or improved products or processes, but which had not produced any results in this period (either because the results were yet to come or because the attempts had failed). If the firms answered positively to one or both of the questions, they were classified as innovative.

Figure 4: Share of innovative firms in the electronics and electrotechnical industries. Norway 1997. Weighted.

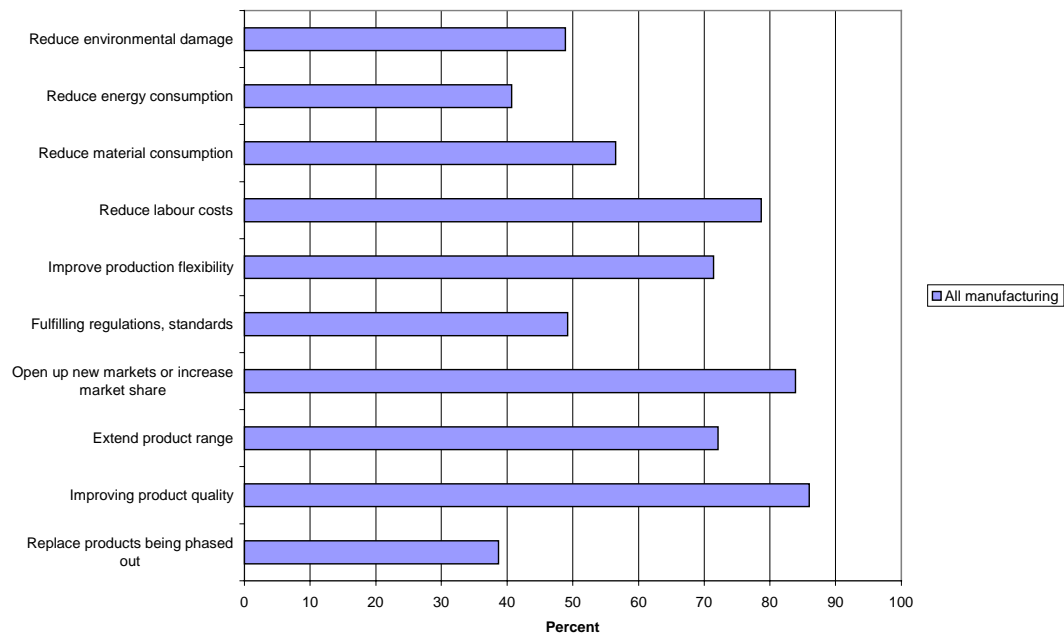


It is not surprising that larger firms are more innovative. Assuming a constant probability to create new or improved products or processes “per employee”, we would get such a result. In our sample, all the firms with more than 250 employees report being innovative, while less than half the firms with between 10 and 49 employees report the same. In general, electronics firms are innovative more frequently than firms in the electrotechnical industry, and this is particularly so among the smallest firms. (Note that there are no data on firms with less than 10 employees in the CIS data.) The figure shows one exception from this general picture: In the size group 50-99, electrotechnical firms are more innovative than the electronics firms. Given the limited number of observations, we would not attribute too much significance to this observation, but rather conclude that the electronics industry is somewhat more innovative, which accords with the common wisdom of electronics as particularly fast changing and dynamic. The electrotechnical industry is not very far behind, however. Also this industry is innovative and the firms would appear to have to cope with a highly dynamic environment.

3.2. Reasons for generating innovations

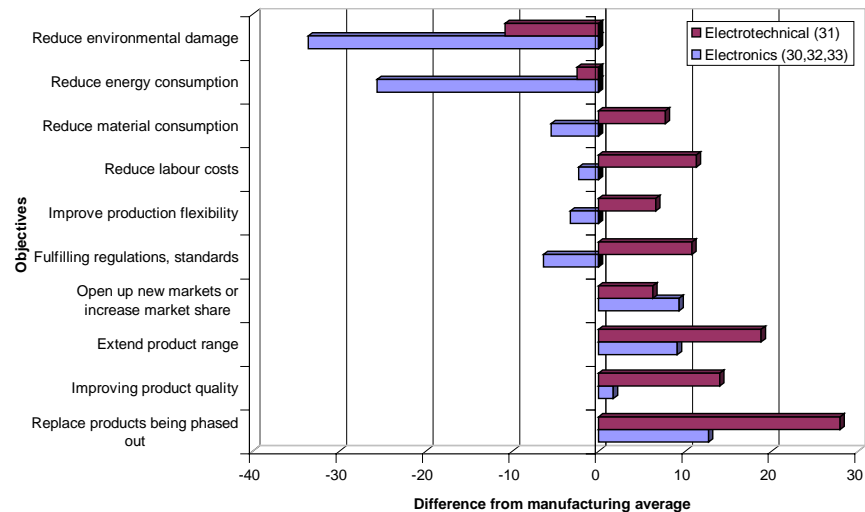
Why do firms innovate? The figure below shows that there are many reasons and motivations for being innovative. The most frequently cited concerns are the need to improve product quality, to increase market shares and to reduce labour costs.

Figure 5: Share of firms that have answered that the following factors are very or relatively important reasons for engaging in innovation. Innovative firms. Weighted shares. Norway 1997.



In the next figure we focus on how the motivation to innovate in the electronics and the electrotechnical industry compares with the motivation of firms in other industries.

Figure 6: Share of firms that have answered that the following factors are very or relatively important reasons for engaging in innovation. Innovative firms. Difference between weighted shares for electronics/electrotechnical and industry average. 1997.



The set of motivations for innovation differs from the industry average, and the two industries we focus on are also different from each other, although the motivation profile of the two also have common features.

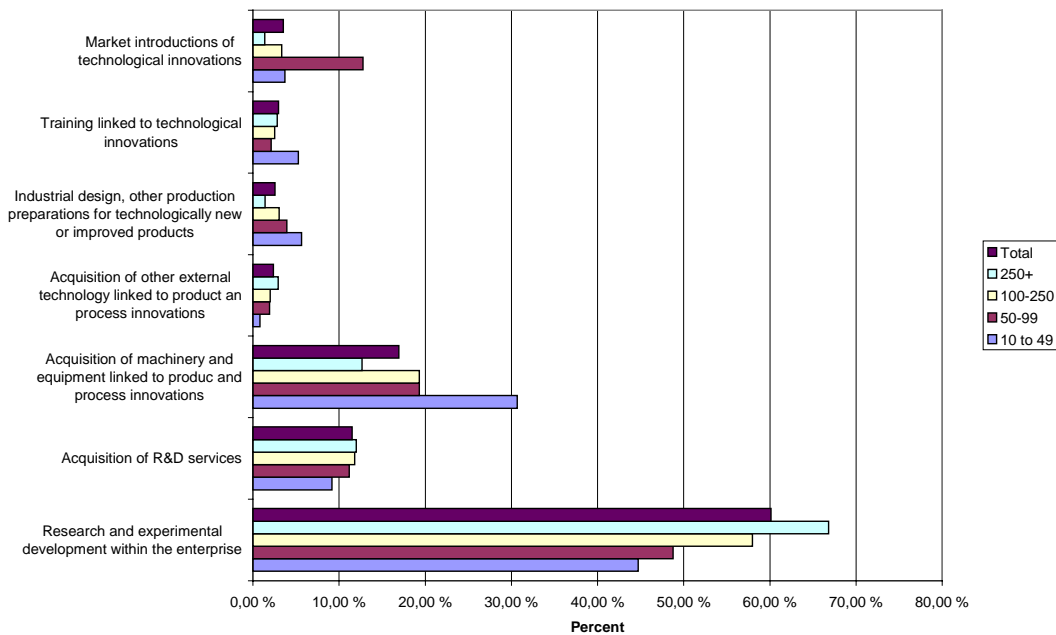
Electronics firms are much less motivated by environmental concerns and by the need to reduce energy consumption than the average innovating firm is. Knowing that there is little or no actual production of electronics components in Norway, thus, that the electronics industry business is about building apparatus from ready-made components, this result is not very surprising. The activity is not polluting, and not very energy consuming. Furthermore, since electronics companies exist in an environment where components are changing rapidly, and technological and business opportunities consequently also are changing rapidly, it is understandable that the electronics industry is more concerned with innovation that can help open up markets, extend products ranges and replace products being phased out. It is in these three respects (and these only) that the electronics industry is markedly more concerned with innovation than the industry average.

The electrotechnical industry is also less concerned with environmental issues than the industry average, also less so than the electronics industry. On the other hand, the firms in the industry is markedly more concerned with replacing products being phased out than the “average” firm. This shows how the industry has to cope with dynamic product markets, and the focus on product quality and product range extension underlines this fact. Furthermore, there are several signs that the actual production, the manufacturing process, is important for firms in the industry. They are more motivated than the average firm to reduce labour costs and materials consumption, and to comply with standards and regulations.

3.3. Innovation costs

How are the firms spending their money in order to generate innovations? The following figure shows the distribution of innovation costs for firms of different sizes.

Figure 7: Distribution of innovation costs on different activities. Weighted shares. Manufacturing industry Norway. 1997.



The biggest cost item is R&D, and the larger firm, the higher proportion is actually spent on such activity. Acquisition of machinery is the second biggest item on the list, and is particularly important for the small firms. Also acquisition of R&D services is common, and amounts to about 10% of innovation costs for firms of all sizes.

In the following two figures we look at the electronics and the electrotechnical industries in comparison with the overall spending on innovation in Norwegian manufacturing industry.

Electronics firms spend less of their innovation resources on acquisition of machinery and production equipment than average in manufacturing industry. The tendency is not uniform, however. The difference is increasing for firms with up to 250 employees, but among the biggest firms, expenditures in this area is in line with the industry average. The electronics firms also spend more on R&D, especially the in-house activities, but also on acquisition of R&D services.

In the electrotechnical industry the patterns are rather mixed. With few observations we should be careful not to attribute too much significance to rather small differences. But it appears that firms in this industrial group tend to spend less than average on R&D. Small firms (10-49 employees) make up an exception: These firms spend more on in-house R&D than the average. Electrotechnical firms also tend to spend more on innovation related machinery and equipment. This holds in particular for firms in with 100-249 employees, but it does not hold for the smallest firms,

which according to the CIS data spend less on this innovation cost item than the average firm of this size in Norwegian manufacturing industry.

Figure 8: Distribution of innovation costs on activity types. Difference between weighted shares for the electronics industry and the Norwegian manufacturing industry. 1997.

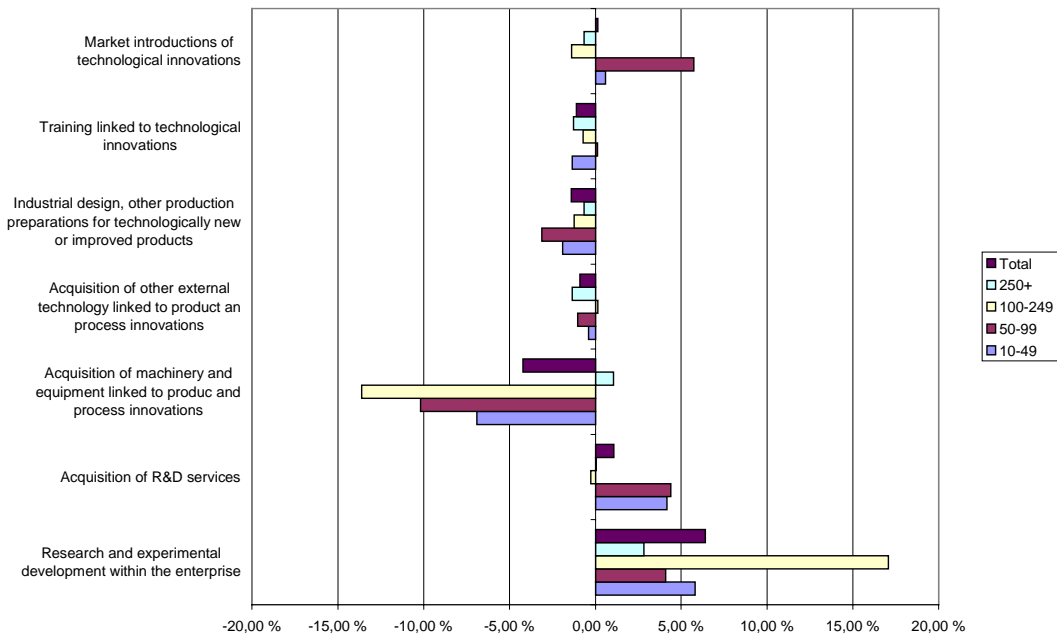
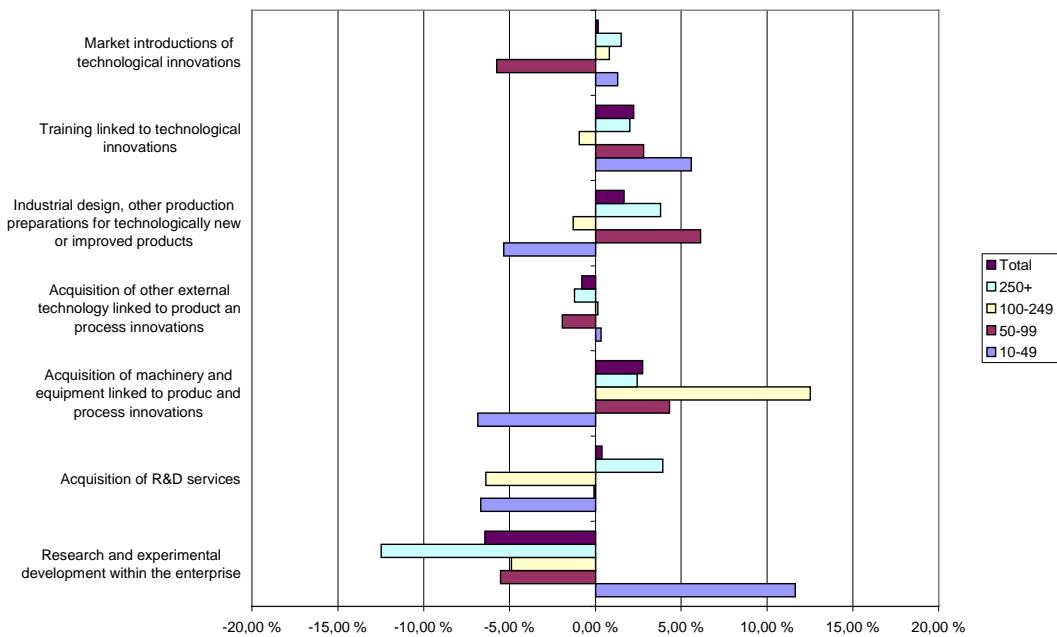


Figure 9: Distribution of innovation costs on activity types. Difference between weighted shares for the electrotechnical industry and the Norwegian manufacturing industry. 1997.



3.4 Technology transfer

How do innovating firms gather information and knowledge, and build competencies in their effort to generate innovations. We first look at what CIS data can tell us about information sources. In the figure below, we see what sources of information innovating firms themselves point out as being important or very important. Internal sources, customers, suppliers and fairs are most frequently cited.

In the subsequent diagram, we look specifically at the electronics and electrotechnical industries, and compare them with the industry average.

Figure 10: Information sources for innovation. Weighted shares of innovative firms characterizing source as important or very important. Norwegian manufacturing industry. 1997.

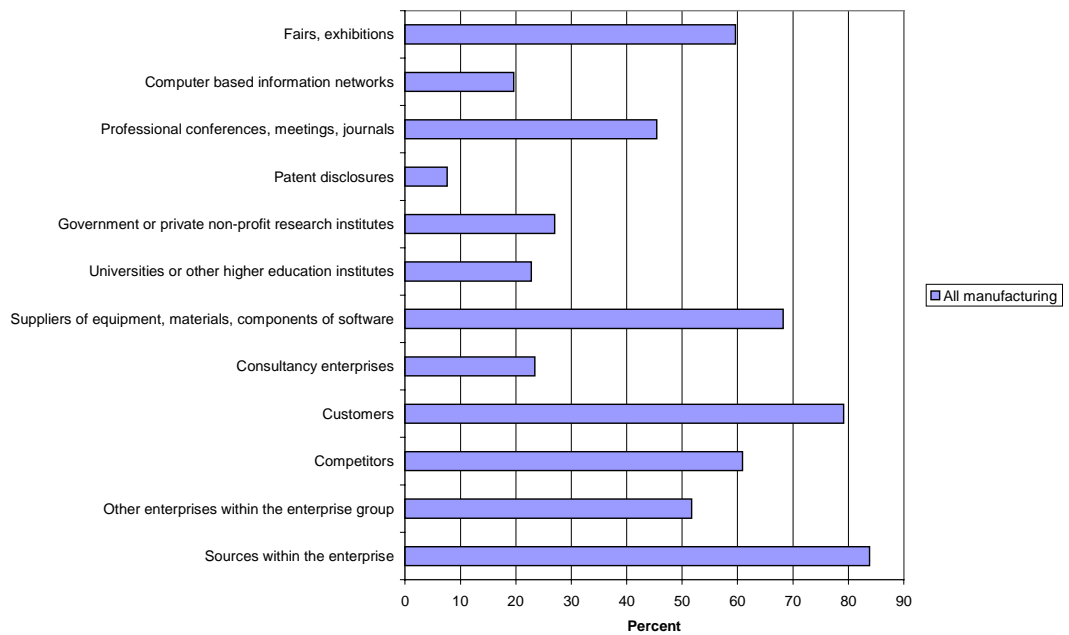
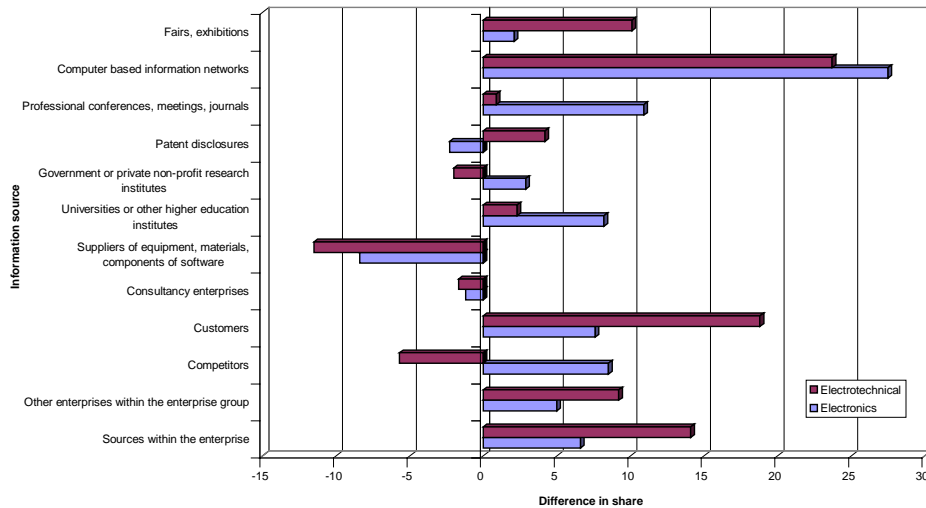


Figure 11: Information sources for innovation. Difference in weighted shares for Electronics/Electrotechnical industry and manufacturing industry as a whole. Norway 1997.



Both firms in the electronics and the electrotechnical industries are much more prone to access information on the internet and other computer based information networks than the average manufacturing firm. Electrotechnical firms less frequently find rival firms to be important sources of information, but in most other cases, firms from both the electronics and the electrotechnical industries tend more often to cite others as important sources of innovation-related information than the average manufacturing firm in Norway. Electrotechnical firms are particularly often getting important information in the course of fair and exhibitions, from customers and from sources inside their own larger corporate structure. Electronics firms much more often than the average manufacturing firm get vital information from professional conferences, meeting and journals, from universities and other higher education institutions, and – in striking difference from electrotechnical firms – from competing firms.

Technology transfer and learning also often happens in collaborative relationships. CIS gives information relevant also with respect this issue. In the figures below, we compare collaboration patterns in the electronics and the electrotechnical industry with the manufacturing industry as a whole.

Electronics firms cooperate much more with foreign customers, and also with other foreign partners, than do the average firm. This is probably because the electronics industry very rarely operates locally: Electronics firms appear to have to operate in international markets to be competitive. Many electronics firms are also parts of large corporations with non-Norwegian head office and ownership, and are for this reason prone to collaborate abroad. In addition to this, electronics firms collaborate

more often with research institutes and in Norway, and also collaborate somewhat more with universities.

The importance of foreign ownership and top management located abroad is even more clear in the case of the electrotechnical industry than in the case of electronics. Collaboration is much more frequent with other parts of the corporation, parts located outside Norway. Electrotechnical firms collaborate more often than the average innovative manufacturing firm with customers, both domestic and foreign, and collaborate more often also with foreign suppliers. Firms in this industry collaborate more often with Norwegian research institutes, but less often with Norwegian universities.

Figure 12: Share of firms co-operating with different partners. Innovative firms. Difference between weighted shares between electronic industry and manufacturing industry as a whole. Domestic and foreign collaboration partners. 1997.

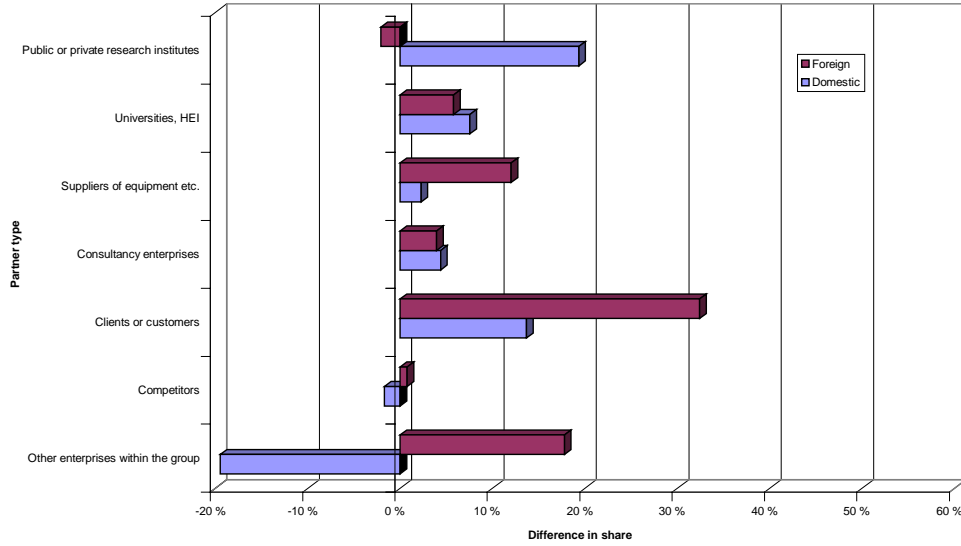
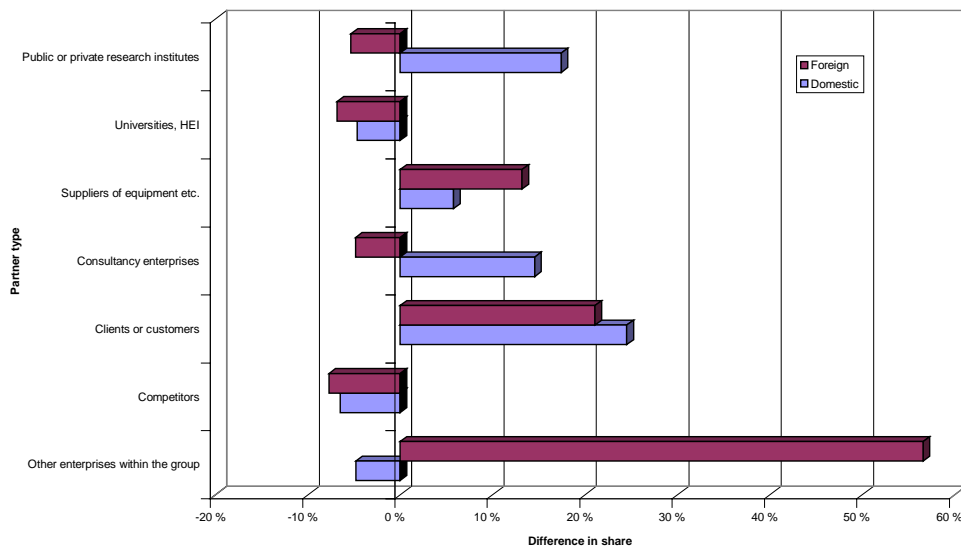


Figure 13: Share of firms co-operating with different partners. Innovative firms. Difference between weighted shares between electrotechnical industry and manufacturing industry as a whole. Domestic and foreign collaboration partners. 1997.



4. Innovation in the electronics industry in Oslo and Akershus

4.1. The structure of the industry and the innovation system

As we now move on to a more hands on empirical analysis of the technology firms in the Oslo and Akershus region, we will have the opportunity to go more in depth on some of the statistical findings presented above.

In this report, we include firms that produce electronic apparatus and computers and other information processing and office machinery, electronic components, instruments (except medical and surgical equipment), television and radio transmitters and receivers, and industrial process control equipment.

Some of the firms we do find when we take statistical data as our point of departure are the following:

Table 5: Selected firms in the Oslo region electronics industry

<i>Company name</i>	<i>Location</i>	<i>Employees</i>
TANDBERG DATA ASA	0883 OSLO	446
SIEMENS AS	0596 OSLO	308
ABB INDUSTRI AS	0575 OSLO	304
NORMARC GAREX AS	0680 OSLO	93
SIMRAD OPTRONICS AS	0661 OSLO	76
PHILIPS NORGE AS	0680 OSLO	68
AUTRONICA AS	0273 OSLO	22
STENTOFON ASA	0617 OSLO	19
CARGOSCAN A/S	0663 OSLO	18
CHIPCON AS	0371 OSLO	4
MALTHE WINJE AUTOMASJON AS	1415 OPPEGÅRD	14
SCANDINAVIAN MICRO SYSTEMS A/S	1414 TROLLÅSEN	10
NERA AS	1361 BILLINGSTAD	574
ERICSSON AS	1361 BILLINGSTAD	508
TANDBERG TELEVISION ASA	1324 LYSAKER	47
SEEM AUDIO AS	1361 BILLINGSTAD	27
MICRONET AS	1324 LYSAKER	6
ECOTRON AS	1473 SKÅRER	61
NORTEAM ELECTRONICS AS	2020 SKEDSMOKORSET	24
ELECTROCOMPANIET AS	1473 SKÅRER	20
TANBERG EDUCATIONAL AS	2020 SKEDSMOKORSET	12
KJELLER MODELLVERKSTED AS	2020 SKEDSMOKORSET	5

Innovation in the sense we are concerned with in this report are closely bound to industrial development; growth and change. To understand the dynamics of the *electronics industry* in the Oslo region and in Norway as a whole, it is important to keep in mind that most of what is going on in this technologically dynamic and economically vigorous industry takes place outside Norway: While other industries – such as significant parts of the electrotechnical industry – may enjoy competitive advantages locally, this in very limited degree is the case in today's electronics industry. Although specialised and niche oriented firms may be nourished by Norwegian firms or organisations with a significant degree of government ownership and influence (Norsk Hydro, Statoil, Telenor to mention the largest), the general trend is a development towards more open and increasingly global competition.

We in this report look at a firm as a value adding organisation which sells products (in a wide sense) in markets (also in a wide sense). When we are interested in the problem situation of firms with respect to innovation, we are interested in the ways

innovation is used with respect to the value adding activities of the firm. The effort to create new products, or to change them, processes (technical and organisational) and markets – which we call innovation – in localised industries which experience competition only within their own geographical and institutional “home” market, will in general involve interactive learning processes where many or all the main types of institutions are involved. (Imagine firm creating a new type of traffic regulation device for the local road system with the backing of local road regulatory agencies, and collaboration with the local technical university and local suppliers and the public road building organisation of the area as “demanding” and solvent customer.) The institutional, economic and cultural freedom to innovate can never be taken for granted, will vary with time and place, and the ability of firms or other institutions to create such space is crucial for the dynamics of any economy.

In general, in Norwegian electronics, the major trends and the most powerful players are abroad. Although it is a fact that some of the basic concepts, methodology, materials and component development (and production) is done in Norway, most of the key methodologies, design principles, materials and components obviously originate from abroad. (As we will see later, the electrotechnical industry differs to some extent from the electronics industry in this respect.)

While the globalised nature of the electronics industry certainly poses *serious challenges* for small Norwegian firms and their ability generate the kind of interactive learning and development processes which are the hallmark of innovation, the liberalisation that has and still is taking place does open up *new possibilities* for this to happen.

Furthermore, due to the reduced scope of idiosyncratic national regulations that give competitive advantages to local firms, the total potential market for any electronics product is increasingly “the whole world”. The reality for many firms is that the openness of world markets (in technological, economic and legal terms) force them to think narrowly in terms of technological scope, but globally in terms of market penetration. It pays off to create specialty products with a high content “embodied” knowledge and competence, and to spread them as wide markets as possible.

What firms can survive in this industry, and what business strategies are viable? In a non-perfect market economy (imperfect with respect to the ideal models of economic theory), firms may not always have to rely on competitiveness with respect to price and quality. A firm must generate more income than costs in order to operate, but this is not necessarily done by producing something that an adequate number of solvent customers will want to buy at a price that makes the business activity generate a positive net income.

4.2. Firms developing quasi-autonomous technology

The development of concepts, methodologies, materials and components is a major cause of dynamics in the electronics industry. (It is obviously also in itself an expression of – an effect of – the very dynamism.) Firms in the Norwegian industry are part of these dynamics. The results of innovative work in science, technology and industry abroad flow represents a constant flow of new business opportunities at the same time as it represents a constant competitive pressure and a threat to ongoing business activities.

Tandberg Data ASA is a publicly held company based in Oslo, Norway. The company is known for its innovation in magnetic storage technology, and is a global supplier of advanced, tape-based data storage products for the professional market. The company offers products for user applications within data storage management through a worldwide channel sales network.

In addition to corporate offices and manufacturing facilities in Oslo, Tandberg Data has marketing, sales and support operations in the USA, UK, France, Germany, Norway, Singapore and Japan.

Tandberg Data was one of the companies that was established in the wake of the Tandberg Radiofabrikk bankruptcy during the 1970ies. The firm was built on a technological fundament of analogue tape recording, which originally was used for recording audio.

Tape backup is a competitive market. Tandberg Data has competitors in its own "global niche" – tape technology - , but also faces stiff competition from other types of data storage (such as the DAT digital tape recording developed by SONY of Japan, and recording systems using other types of media (such as compact disks – CD-RW and DVD-RAM – and optical disks).

Tandberg is developing its own technology, the SLR tape technology. With the SLR product line, the company believes it has a good basis for future development of its data storage business, and wish to focus on further developing its own proprietary products based on this technology (Annual report 1998).

The competitive challenge Tandberg Data faces consists in having competitive products in terms of performance (speed and reliability) and pricing. In addition, there is a strong demand that products both are backward compatible (old data must be accessible with new equipment) and that the technology has a credible development path ahead of it (data storage volume that needs storage is increasing strongly, and customers want to know that more powerful products will become available over time.)

Tandberg is traditionally and fundamentally technology based firm, with a strong development milieu and a strong engineering culture. However, the firm today see it as important to be (and to be perceived as) customer oriented, and stresses the significance of support and service). Furthermore, management is also focusing on the need to development the work organisation; to enhance creativity essential for developing the business in the longer term, while at the same time keeping costs down and securing day-to-day profitability.

How is knowledge generated and skills developed in order to develop the firm in all the pertinent areas? Obviously, much is done through recruitment. Managers develop in the organisation, and people with managerial skills are also recruited outside. People with technical skills are recruited from universities and other firms; around 200 engineers work in development and production in the Oslo headquarters.

But this is only the beginning. The core competencies that make the organisation effective and efficient, and that makes the firm a technology leader in its chosen area depend on ongoing learning and development, which in part is an "intra-mural" activity, but which in a significant degree is taking place in interactions with other institutions. The Tandberg Data firm has close collaboration on research projects with research institutes, such as SINTEF in Oslo and Trondheim, and with institutions abroad. There is furthermore close collaboration with suppliers of components and materials. Increasingly, Tandberg Data is also establishing partnerships with their major customers (such as IBM and other computer systems manufacturers) and with other firms in the same industry (such as Quantum of the USA).

All these relationships are interfaces for interactive learning processes that are essential for sustained competitiveness and technological leadership of Tandberg Data.

Tandberg increasingly feels the need to make alliances both to develop the strategic dimensions of the overall business, and to develop the technology basis of the future. The company has good experiences with such collaborations. They have very good experiences

commissioning out research and development tasks to SINTEF (mainly SINTEF Trondheim, but in some cases also SINTEF Oslo), and also have a collaborative project underway with people at the University of Oslo. In practical terms, SINTEF is perceived as professional and easy to deal with, while the University is a large bureaucracy where many decision making levels have to be involved, and where the practical aspects of collaboration may be severely hampered by the fact that the university decision making system is slow, and the time the university needs to get practical arrangements in order is excessively long.

However, the crucial problem is to find people with the needed competence. The weakness of the electronics industry – and in particular the data storage industry – in Norway and in Europe is a problem for Tandberg Data. There are few firms with relevant core competence, and few academic and research milieus that possess competence that is desired by Tandberg Data. Most of this competence is located in the US, and although Tandberg has access to some of the relevant technology centres there, it is difficult to reap the same benefits from them as do firms in the American storage industry.

Source: Author's interviews with employees, information from company's web site.

Technology ICT firms in the Oslo region, such as Tandberg and Norman, depend on autonomous R&D capabilities. One of the keys to successful operations is the linking of research and development concurrently to commercial operations and needs of the firm, and to other knowledge generating milieus around the world. The larger the firm, the more does the firm itself develop its links and relations within the industry and the wider technology field in which it is operating. The bigger firms, and the more advanced and commercially appealing and exclusive the technological capacity of the firm is, the more can the company have the ambition to influence development directions in the field where it operates. In the case of Tandberg, the company has chosen to pursue one line of development in which it has a decided technological advantage. Faced with competition from rivalling technologies, the firm has strived to build collaborative relationships to main players in the ICT industry. Tandberg has taken the role as OEM for firms such as SUN and IBM. In this way, one has tried to compensate for the dangers of choosing a narrow technological fundament, by building strong collaborative relationships with strong and demanding customers.

On the technology side, an earlier tendency to base development on internal resources and intra-mural learning processes has been weakened, and there has been a gradual opening up towards learning interactively with external competence milieus, such as research institutes and universities. Such relationships are of mainly two types: Short term projects, extending from a few weeks to several months, financed by the Tandberg Data, undertaken by applied research milieus such as SINTEF, and longer term projects, undertaken in universities, where Tandberg may contribute equipment and partial financing.

The benefits from managing to dominate crucial technologies can be enormous, as role model firms such as Microsoft and Intel have shown. But most firms, and almost all firms in the Oslo regions, are small and medium sized firms which however narrow they define their technological basis, cannot aim to steer technological trends, but have to suffice to follow the trends and to ride the fragments of the large waves that end up in Norway.

The dynamism in the industry; the ever economies and technological opportunities of materials, components and design principles, are both a threat and an opportunity (as we see illustrated in the case of Tandberg Data.) Innovation also has a dual character: One type of change is “quantitative”; components can do much more of what they

do, or do the same at a much lower cost. (Personal computers and their components tend to cost the same, but their performance go up all the time.) The significance of this type of change should not be underrated, as it can be a major factor behind growth for long periods of time. However, there is also more demanding cases of change, “qualitative” change, which means that something really new happens which has important and often unpredictable consequences.

Such changes often are incompatible with existing economic, technological or social practices, and may force radical and costly changes onto existing institutions. *Small firms* may often be the first to exploit the potential benefits of such changes. Small firms can find niches where they employ new design principles, materials and components in profitable business operations long before large firms find it opportune to do the same.

Tordivel AS is a company based in Oslo, Norway, providing programming services, turnkey vision systems, and specialized and standard equipment for use of computers in primarily technical applications. The company currently employs twelve highly skilled engineers, organized in two departments – industrial inspection and software development.

The firm started off as a one-man business in 1992, as a consultancy which did programming work for major Norwegian companies. Tordivel soon established itself as a software and hardware sales business, representing foreign firms which provide products usable in small-scale or large-scale industrial systems where signal or image processing is part of the task at hand.

Tordivel early in 1997 established a department to produce camera-based solutions to cutting-edge manufacturers. The department today employs six persons among these three highly skilled vision engineers. The goal is to make solutions using world-class components from leading companies such as Cognex Corp, USA, Image Industries, UK, and Lord Ingegneri, France.

Tordivel has managed to generate considerable growth during its first years of operation by utilising new and advanced components originating from abroad in projects aimed at developing cost effective process solutions for industrial customers in Norway with activities in the industrial automation field. These customers have been production companies (such as Iplast AS) automation equipment manufacturers (for instance Norcontrol and Autronica) and for research institutes (Sintef).

These activities have been in part facilitated and promoted by public agencies which aim at contributing to technological innovation and business development. Development projects have received support from the Norwegian Research Council and from SND. *SND Invest* at the end of 1998 made a 2,5 MNOK investment in the firm (in a private issuing of shares).

The company interacts closely with other suppliers, customers and research institutions and this interaction is a major factor in the learning processes that the firm depends on for its continued existence. Key competence must also enter the firm by way of recruitment of new people, which often come from other electronics firms. Most of the technologists in the firm are graduates from the Norwegian Technical University in Trondheim). The recruitment issue has at times been a major bottleneck. According to the director of the firm, Thor Vollset, the firm struggled for more than two years to get hold of a competent software developer, without success. As a small firm, the task of locating and attracting young talent at times appear to be an insurmountable obstacle to growth. (Source: Interview with employee development engineer, and information from <http://www.tordivel.no/pressemeldinger/software.htm>)

The firm **Electrocompaniet** was established in Oslo in 1972 with the purpose of developing and producing high performance and high fidelity sound systems with an electronic design which was completely different from other designs. The design were based upon a new approach to transistor amplifier design developed by Dr. Matti Ojala and Jan Lohstro. The result of their innovative design work were incorporated in the first Electrocompaniet design, a 25 watt amplifier.

Electrocompaniet's experimentation based on this new design and the company's desire to create transparent, neutral powerful amplifiers led to a search for, and discovery of, a new way of using feedback in amplifiers. Since then the company has experienced fewer design limitations. Years of comprehensive testing and research have resulted in the current designs using an approach to the output stage not seen in other amplifiers.

All Electrocompaniet products are made by highly skilled technicians, and extensively tested for maximum performance and reliability. Electrocompaniet amplifiers are sold in more than 25 countries.

The company has built a strong development group, but the firm is a small one, currently employing about 20 people. The firm wishes to grow its business, but experiences "loneliness" in its location in the Oslo-region. In the early years, when the consumer electronics firm Tandberg was still operating, it was easier to get access to relevant resources; both in terms of components, materials and methods. The company to a large extent relies on this stock of knowledge and competence, key personnel have stayed with the firm for a long time, and learning happens in a trial and error process, and in an interactions between developers in the field and people in organisations interfacing with the company, such as suppliers and buyers.

As a small company, Electrocompaniet does not have resources to continuously map opportunities offered by public agencies to support development of SMB's and innovation. Furthermore, interacting with advanced research milieus is difficult. The company has specific needs which do not often match the interests of researchers in such milieus, and the company does neither have the resources needed to participate in long terms research efforts with uncertain results, nor the power to influence research directions in external R&D milieus.

Source: Interview with manager, with employee of subcontracting firm, and information from <http://www.electrocompaniet.no/>

4.3. Venture capital driven company growth

The firm **Akamai** was established one year ago by a professor in applied economics at MIT in Boston, and one of his students. The business idea was to develop a technology that removes bottlenecks on the Internet by storing content closer to users. Two of many interested US venture companies invested about 10 million USD. With first class stock options Akamai managed to attract the earlier CEO of Time Inc., and other highly competent managers.

With a good business idea, experienced leaders and solid financing there was full speed ahead for Akamai. A development contract with Apple gave Akamai a name, and during spring the first articles in US media appeared about this potential future winner.

Monday November 2, Akamai was introduced on the stock exchange. The share price increased 458 percent the first day. The price Wall Street set on Akamai was more than 10 billion USD (more than Norways biggest industrial firm Norsk Hydro) and the two founders possess stocks worth about 1,5 billion USD. So far Akamai has had a turn over of about 1,5 million, and has made a net loss of about 30 million USD.

Source: Nettavisen. (http://www.nettavisen.no/nett_paa_sak/79988.html)

The Akamai story may be extreme, and it is about a firm far away from Norway. Still, the story is a nice illustration of a kind of financial business logic that is in no

way unique. The finance “cylinder” mentioned as one of the main contributors of power to the engine of change in the electronics industry is particularly important in industries that people in the financial sector consider “hot”; for the time being this most often is business activity related to the Internet and to so-called web technologies.

Norman Data Defence Systems claims to be a world leader within the computer security industry. The Company develops and markets enterprise-wide security software solutions, and its product set offers solutions for virus detection and removal, access control, data encryption, risk management, and Internet connectivity. Founded in 1984 in Norway, Norman today has operations in North America, Europe, Asia and Australia and employs more than 250 staff worldwide. The Norwegian headquarters are located in Lysaker.

The company's share-price increased 300 percent over the last year (3.11.98-3.11.99), but operating profits have been negative both this and the previous year.

Source: Author's interview with employee; information from <http://www.norman.no/>

4.4. Firms developing complementary technology

There are many real life situation where firms do not need a decisive technological advantage, or even a competitive advantage in terms of price/quality in order to manage to generate a positive net income. There are several cases of firms that are favoured suppliers, and for a variety of reasons. A state owned company or a public agency can choose to buy from a local producer as long as the product is within a given price/quality range. Similarly, small firms can be preferred because of seemingly irrelevant factors such as personal knowledge and relations between individuals, belonging to the same locality, etc. However, in addition to political and social reasons, valid *business reasons* can give rise to the existence of companies which are not able to assert themselves in competitive markets. The willingness to follow the lead set by a large customer, for example, may give the client firm such an advantage in terms of flexibility and/or control that this outweighs the particular disadvantages of dealing with this particular supplier.

Furthermore, the ability by large customers for many other reasons. That they are small may mean that they do what the customers want, but it may also be that personal relationships are the fundament upon which the business relationship rests.

In spite of many such examples, there can be no doubt that many firms in the industry are exposed to real market competition, and can neither survive nor grow without being competitive in terms of product features, price and quality. Most of the time, competitiveness rests on a complex of technological prowess, logistics capabilities, production skills, and customer knowledge. In addition they may have competitive advantages that relate to regulatory conditions and regional specificities.

Time Recorder Co AS is a 100% Norwegian owned company, located in Oslo, and is the oldest, largest and the leading supplier of time recording equipment and systems in Norway. The firm was established in 1914, and the customer base counts more than 8000 firms.

Time Recorder Co AS has a supplier network that covers the whole country. The firm has its own development group, highly qualified employees, and runs an around-the-clock customer service and support operation.

The product portfolio consists of three different time recording systems, which can be connected to computer based administrative software solutions such as SAP, but also to specific "Windows" based systems produced by Norwegian firms. Furthermore, Time Recorder acts as exclusive agent and distributor of the German manufacturer KABA-Benzing on the Norwegian market.

Time Recorder builds complete solutions for customer, utilizing hardware from the German manufacturer. In this set-up, Time-Recorder plays the role as software partner and agent versus its main supplier, and as complete solution provider towards its Norwegian customer base. (See illustration.)



That Time Recorder is exclusive agent for KABA-Benzing in Norway, means that the firm sells hardware also to its local competitors in the time measurement systems market.

Time Recorder explains its dominating position and competitive advantage on the Norwegian market in large part as a result of its own effort to develop software which is tailor made for Norwegian firms. The specificities of Norwegian working time regulations and agreements, which to a significant extent is industry and business specific, means that adaptation of foreign and standardized systems is less attractive. Customers buy tailor made software systems, and they pay a mandatory support fee, which contains software updates which take care of changes which are called for both for technical reasons (for example changing base software on clients' computer systems), as well as for legal and other reasons (for example new rules governing flexible working times in firms).

Sources: <http://www.timerecorder.no/> ; <http://www.kaba-benzing.com/> ; Kapital Data 11/96 ; author's interviews with Timer Recorder employees.

4.5. Knowledge transfer, distribution and advanced logistics

As a natural consequence of the globalised nature of operations in the electronics industries, many firms build their core competence on a mix of own development efforts and input from firms abroad. Time Recorder is but one of very many such firms. The fact that electronics business to such a large extent is about designing artifacts of materials and components mostly originating abroad makes the business of industrial intelligence a major business opportunity in itself. What components and materials are available, at what price? What is the price development curve for a certain component, or class of components? How will availability be over the next few months? A plethora of agent firms make a living of selling a smaller or larger set of products relevant for firms in the industry. Many are small, and are striving to grow their business. They build their competitive position mainly on the **price/performance** characteristics of their products. Others are small, but have deep

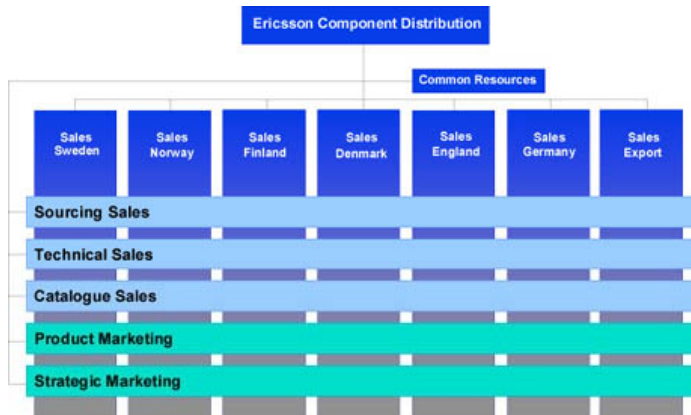
expert knowledge of what they sell, and in effect operate as **knowledge intensive business services**, which not only sells the hardware that they bring into the industry, but act as a consultancy on the components, materials, process methods and design principles which are important for customers. Finally, some much larger firms with a large product portfolio builds competitive advantage by in effect operating as advanced **logistics** firms. Their business is about funneling large volumes of materials and components to firms that need them, and that need them “just in time”, in known adequate volume, and at within an pre-set price range.

Arthur F. Ulrichsen, Oslo, is a trading company which has a broad product portfolio for relevant for electronics and electrotechnical firms. The firm uses mass distribution by mail of catalogues and (increasingly) its presence on Internet as its main channel for publicizing its offerings. The firm mainly bases its sales arguments on price/performance and quality/scope of its product range. However, in some of its PR material the firm also stresses the knowledge that their sales people have of their products

Teleinstrument AS in Lillestrøm is agent for leading producers of production machinery. The firm offers the hardware, coupled with support, service and tailoring of systems to the specific needs of customers.

Morgenstjerne Teknisk AS, Oslo, supplies advanced and costly measuring equipment for use in laboratories in research and in industry. The firm represents Tektronix in Norway, as a service and support organization. It has deep knowledge on the equipment, calibration procedures etc., gained in part through in-house training at Tektronix in the US, and complemented with on-line support access to the US firm. After sales support therefore is crucial for the firm's business, which in effect is a knowledge intensive business service.

Ericsson Component Distribution, Billingstad, is part of the Swedish Ericsson company. The Distribution business is a technical distributor of electronic components. The main sales arguments that the firm focus on is its combination of expert technical application support with ex-stock availability and express deliveries from a large central warehouse. Ericsson Component Distribution argues that it can provide a complete component supply solution, and that it is able and willing to work closely with the customers own logistics and technical experts, to ensure the most efficient and cost effective approach to component sourcing. Expertise in technology and logistics is combined with a broad product mix.



Source: Information from web sites of respective firms. Interviews with managers/employees.

4.6. The role of policy and the regulatory system

We have discussed three driving forces of change in the electronics industry. The fourth factor mentioned earlier is policy and the regulatory system. It is not obvious that this can be said to be a driving force in itself. In many cases, policy can not do much more than modulate and influence the direction of efforts to innovate that are motivated by interests in technology, in making a profit, or in the attractions of building new businesses.

When we discuss this with people in innovative firms, they very often cite negative impact of the government system of the possibilities to develop a business and to innovate. Firms are faced with a plethora of demands and regulations, and the policy system siphons off significant resources from firms. Asking people in the industry how the policy system can contribute more positively and be of real help, the first answer they have is usually that one should stop interfering and stop making life difficult for people who try to grow their business and to innovate.

In this perspective, we could speak of a fourth cylinder in the engine of innovation and change lacking the necessary spark, or lacking the mix of ingredients which could make the piston contribute force, rather than drain force from the engine as a whole.

However, to say that the role of the policy and regulatory system is only negative would be misleading. The cylinder does contribute, although certainly not optimally. The government system locally and centrally does – to cite one example – contribute to realising innovation by making regulations that modulate and give a positive turn of direction to innovative efforts, such as when products are subsidised or given differential treatment, for instance in the tax system, and when support for innovation and development efforts are given conditionally; for example on the basis of collaboration between firms or between research institutions or university institutes, and firms.

But the policy system has a further significance: The large – partially or wholly – state owned firms play a strategic role in Norwegian industry. The role of Telenor is interesting and relevant in this respect: The company owns (after spinning off or acquiring) a large number technology based and knowledge intensive firms, and constitute a major venture capitalist and coordinator of knowledge intensive business operations in the information- and communication technology field in Norway; both in industrial operations and in R&D activities. Telenor is a very important player in the Norwegian ICT industry as a whole; it embodies large parts of the ICT innovation system as a whole in Norway. It is closely connected to the governance system in Norway, it is a very significant customers for a large number of firms, it operates significant commercial operations, and it is a heavyweight in ICT research and development, both through its own in-house R&D operations and through its close links to other research milieus and knowledge intensive business firms. These facts, and the fact that the institutional structure of the whole telecommunications area in Norway (and internationally) is in rapid change, makes it obvious that a further analysis would be called for in order to get an adequate grip on the ICT sector in Norway. For resource reasons this analysis cannot be pursued further in the present report, however.

5. Innovation in the electrotechnical industry

5.1. What is the electrotechnical industry?

In this report, the electrotechnical industry encompasses firms which produce electric domestic appliances, firms that produce electric motors, generators, transformers, cable, accumulators, lighting equipment etc.

The electrotechnical industry is more than a hundred years old in Norway. The first turbine used to operate an electrical generator was installed by *Myrens mek. Værksted* in 1885. Since then, the whole hydroelectric power-related equipment industry developed alongside the development of Norwegian hydroelectric power. The industry grew between 1945 and the 1970's, but stagnated somewhat at the beginning of the 1990's.

Some of the firms of the Oslo and Akershus electrotechnical industry that we find in the register data from 1996 are listed in the table below.

Table 6: Selected firms in the Oslo region electrotechnical industry.

ELECTROLUX NORGE AS	2073 BØN	187
ABB NORSK KABEL AS	2150 ÅRNES	183
CTC FERRO FIL AS	2151 ÅRNES	31
ESI AS	2150 ÅRNES	30
A-KABEL AS	2150 ÅRNES	17
NES TEKNOLOGIPRODUKSJON	2151 ÅRNES	5
ALCATEL KABEL NORGE A/S	0581 OSLO	164
ELEKTROVAKUUM AS	0483 OSLO	101
SIEMENS AS	0596 OSLO	100
LUXO AS	0680 OSLO	51
EXIDE SØNNAK AS	0583 OSLO	36
NORSK ELEKTROMOTOR A/S	0653 OSLO	13
HAGAN ELEKTROOVNER A/S	0668 OSLO	4
TRAFONIKK AS	0186 OSLO	4
ALCATEL KABEL NORGE AS	1405 LANGHUS	98
ELDRIVE AS	1550 HØLEN	67
LANGSJØEN ELEKTRO AS	1410 KOLBOTN	22
ELECTROMATIC TELELINK AS	1405 LANGHUS	3
ELEKTROKONTAKT A/S	1300 SANDVIKA	121
ASEA BROWN BOVERI AS	1362 BILLINGSTAD	50
ELPLEX AS	1380 HEGGEDAL	27
UNITECH A/S	1344 HASLUM	11
ELEKTROFABRIKKEN AS	1351 RUD	5
NORWESCO A/S	1471 SKÅRER	67
IMEK AS	1476 RASTA	47
MELBYE ENERGI A/S	1940 BJØRKELANGEN	17

The industry is heterogeneous in several respects. Firms are different with respect to size, with respect to ownership and organisational structure, with respect to technology and knowledge basis, and with respect to innovation.

In the following, we have decided to make a case oriented and qualitative analysis of the industry, discussing three main types of businesses, which covers most of the Norwegian electrotechnical industry:

- (i) Engineering oriented production firms in the energy industry
- (ii) Electrotechnical firms producing technical products and equipment for professional use
- (iii) Firms producing consumer durables

5.2. The hydro-electric energy industry: Multinational corporations in a national context

The electrotechnical industry is older, bigger and more complex than the electronics industry in Norway. Several large international corporations have significant operations here, and many have head offices in the Oslo region. The firms are generally diversified, with several sets of products, building on different technology areas and with different knowledge bases. But their fundament has been the hydroelectric energy production. There has been a continuing effort to exploit watercourses and waterfalls in production of electric energy throughout the century, and this has given rise to a strong industry producing advanced turbines, transformers, cables and other artefacts needed for the production, distribution and consumption of electric energy.

Firms such as *Alcatel Kabel*, *ABB Energi*, and *Siemens* are among the large firms in this business. Over the years, these firms have built strong engineering and development milieus, in addition to building strong production units. At the same time, knowledge-institutions (such as the *Energiforsyningens forskningsinstitutt* at NTNU in Trondheim, and *Institutt for Energiteknikk* at Kjeller) has built a significant competence in this area. There has also been a sustained professional education of engineers for almost a century. Furthermore, this industry has been well connected to the Norwegian governance system, through its close links to NVE (*Norges Vassdrags og Energidirektorat*), and it has been well represented also in and by the research financing system, and the Norwegian Research Council (NFR).

Alcatel STK and Alcatel Kabel

During the last 80 years Alcatel STK has played a leading role in the development of telecommunications and the supply of energy in Norway. The company was established in 1915 under the name Skandinaviske Kabel- og Gummifabriker AS, and was subsequently merged with Standard Electric AS in the 1930s, which later became International Telephone and Telegraph Corporation (ITT). The company then changed the name to Standard Telefon og Kabelfabrik AS (STK). 1987 was another important milestone in the history of the company. ITT sold its majority holdings to the newly established international group Alcatel, and Standard Telefon og Kabelfabrik AS was renamed Alcatel STK AS.

Alcatel STK is one of Norway's leading companies within the complex technological fields of telecommunications and cables and cable systems with an annual turnover in 1996 of almost 4.32 billion Norwegian kroner. The company has 2500 employees and has production and operation facilities in more than 20 locations around in Norway. The company's turnover is increasingly based on export, an integral part of the company's strategy. The company comprises the parent company and three main subsidiaries, Alcatel Telecom Norway AS,

Alcatel Kabel Norge AS, and Alcatel Distribusjon AS. In addition there are nine other wholly or partly owned companies within the Norwegian Alcatel group.

Alcatel Kabel Norge AS: Cable and cable systems in Alcatel STK in Norway is organized under Alcatel Kabel Norge. This company develops, manufactures, markets and installs offshore, land and submarine cables for power transmission and telecommunications. The company claims to have played a principal role in the development of energy supplies in Norway, widely known for its highly developed use of water power supply.

Many of the projects undertaken by the firm involve new technology where sophisticated facilities and top qualified personnel are needed to ensure successful project completion. The company claims to have a strong technological background and extensive engineering capabilities, and reflecting these qualifications Alcatel Norway has achieved the status of competence center for offshore products and submarine cables within the Alcatel group, which the worlds largest cable manufacturing enterprise.

Some historical highlights of the cable factory's history are the following: The company started producing paper insulated wires in 1919, and there has been a tremendous and continued development of competence and production capabilities: In 1939 the first oil filled high tension power cable was supplied to Oslo. In 1973, contract was established with the Norwegian State Power Board for development of DC High Tension Power deep sea cable for connection between Norway and Denmark. The company started building of a new high tension power cable production plant in Halden. 3 years later, the first deep sea high tension power cable across Skagerrak between Norway and Denmark was successfully laid and put into operation. In 1984 the firm completion of the world's biggest submarine cable installation consisting of 225 kms of 525 kV AC submarine oil-filled cable between Vancouver Island and the mainland of British Columbia. (This is still – in 1999 - the world's largest submarine cable installation.) The first prototype of the world's most powerful DC submarine cable certified for carrying as much as 800 megawatts was presented in 1997.

Source: <http://www.alcatel.no/>

The complex of industry and research in this area appears to have been well developed, and it is reasonable to characterize this as one of the most significant innovation subsystems in Norwegian industry, and in the Norwegian economy as a whole.

In spite of constituting a well established production and innovation system, this industry sector today is faced with severe problems. The problems appear to have a similar origin as the problems of the firms in the petroleum sector: The era of the large infrastructure investments is coming to its close. In the same way as the development of new oil and gas fields in the North Sea is loosing momentum because few economically attractive new discoveries are made, most of the large watercourses have already been exploited, and it proves increasingly difficult to find political support for exploiting what remains.

The problems are the same, and it is interesting that the firms to some extent are the same too. ABB and Alcatel are only two examples of two firms which both have invested heavily in offshore, after having grown to significant industries in Norway developing local hydroelectric energy sources.

In the diagram above, the structure of the innovation system in the electrotechnical industry has been illustrated in the same fashion as we depicted this system for the electronic industry earlier. (The illustration could be taken to illustrate some main features of the off-shore industries as well.) The main differences we wish to highlight between the two industries are the following:

- (i) The most significant firms are large international corporations.

(ii) The major markets are domestic, and closely coupled to the system of governance. Markets to a large extent consist in public sector investments in public and state owned infrastructure.

(iii) There is a higher content of domestic inputs to innovation and business development; both in terms of technological knowledge and development capabilities, materials, components and production equipment.

Policy considerations

Faced with economic decline, which has its most obvious and immediate cause in lack of political will to make further infrastructure investments in the energy area, the industry appears to argue mainly along two lines:

First, it is claimed that the consumption of electricity continues to increase, so that we simply have to produce more if we do not want to import ever more electrical energy, and if we do not want to be faced with actual cut-offs of supply due to lack of production capacity when demand is at its highest. We have to continue to develop hydroelectric power, but – and at this point it is significant that many electrotechnical firms have invested heavily in the off-shore area – also to move into energy production using petroleum resources as the energy source. Gas based electricity production is an obvious alternative where existing firms could potentially find a new market, and where public investment in infrastructure could pay off, both in terms of increased production of electricity, and in terms of more business for industry.

Second, industry representatives argues that it is important to replace existing installations: Public funds are called for in order to replace existing plants, in order to secure continued production in the existing power plants.

We cannot pursue the complex policy debate here. It is important to note, however, that the energy related electrotechnical industry and the innovation system that has been built around it, is faced with a very difficult situation. The traditional approach to business development and innovation is under pressure. The industry itself appears to be conservative; well established, used to a certain type of interaction with public authorities, and sceptical with respect to the chances to succeed in a situation where more fundamental innovation behaviour is called for. Would the firms manage to build a business and new innovation in areas such as bio-energy, wind energy and other alternative and sustainable energy technologies? Today, there are entrepreneurial firms in Denmark that are far ahead of the industry in Norway. Can new or existing Norwegian firms establish themselves in these areas? Are the other partners in the existing innovation system able to join forces with industry in changing research priorities, in developing new technologies and new markets? The challenge that has to be faced is to manage to become competitive in internationally, in research, technology development, engineering design and production, in areas where Norway does not possess natural resources that give the players a significant competitive advantage.

5.3. Electrotechnical firms producing accessories: New stories of globalisation

Electrotechnical component production, for example production of electrical infrastructure in buildings, has historically been a labour intensive process, mechanical in nature, based on the use of metal, ceramics, and increasingly new materials such as plastics. Gradually, mechanical construction principles have been replaced by electronic devices. Furthermore, new applications have emerged, where the property of electricity as a vehicle for transmission of power is no longer the crucial one. Rather, it is the information carrying capacity of electrical currents that is the essential. In other words: Firms which traditionally has been electrotechnical and energy oriented are gradually moving into the ICT industry in two ways: First, by finding new applications for their basic products, devices to build cable networks. Second, by applying electronics in their energy oriented applications. A simple example is electronic dimmers, surge protectors and fuses in the electric infrastructure of buildings. But this integration goes further, as can be seen when we note for example how cables for transfer of electric energy can serve also for information transfer, and how integrated automation systems encompassing data and voice information systems, lighting, climate control, security monitoring and more are built into modern buildings.

This increased complexity has come at the same time as local governance conditions gradually have given way for international standardization. The days of proprietary design of electrotechnical equipment in every nation are long gone. Data cabling follow international industry standards, and increasingly also equipment used for the consumption of electric energy are becoming uniform across national borders.

Traditional firms which have had special competitive advantages under the old regulatory regime increasingly are facing international competition. This is a threat and it is an opportunity. It means that firms will meet increased pressures in their existing markets, at the same time as the potential market opportunities for a firm increases vastly.

Elektrokontakt AS, the Lexel Group and Schneider Electric

Elektrokontakt and Norwesco are two Norwegian electrotechnical firms which have traditionally produced a similar range of equipment useful for the end-user consumption of energy. The firms have produced devices used by electricians, such as switches, plugs, outlets, fuse racks and fuse boxes, etc. Design and production has to a large extent followed German industrial norms (DIN), but the firms managed to establish themselves and to maintain a leading position in the Norwegian home market.

Elektrokontakt AS

Elektrokontakt was established in 1946, and is the biggest firm of its kind in the Nordic countries today. The firm had 240 employees and a turnover exceeding 350 million NOK in 1997, and operates two modern production facilities in Norway. The firm is renowned for its capacity in injection moulding, and has a broad and competitive product line in electrical components, aimed at the professional market for electrotechnical installation. The traditional market of energy related equipment is rapidly being complemented with products for laying out ICT networks in buildings, and also equipment of more advanced nature for automation and control in large buildings are being sold (partly under the brand name ElkoMatic).

The firm has traditionally developed and manufactured inside its own premises. The firm has an in-house development department, and does much of the design work itself. The

development department have traditionally based its efforts on in-house competence. While interviewing one of the senior developers, the signs that we are faced with a self-confident and self-reliant development milieu are very clear. Most of the significant ideas for real innovations in the products are generated in-house, and experiences with outsiders, researchers (such as at SINTEF) and in design studios are considered unequivocally to have been failures. The key to success is in the firm itself and its staff: Skills and knowledge developed over time, working intimately with an advanced production department and with demanding customers. Responding to direct questions, he stated that the key to success in general would be to let Elektrokontakt continue as an independent business. Furthermore, when asked about what policy makers could do, he pointed out that there is a lack of people with skills in mechanical construction which is a real problem for the firm, and as for what the local authorities could do better he stated that "they could have done something five years ago, when we wanted to expand the production facilities, and they didn't let us".

Elektrokontakt used to be family owned. It had a clear market focus and a clear product strategy. However, the trends that mark the industry have also affected Elektrokontakt. The firm was acquired by the Finnish firm A. Ahlstrom Corporation, which then went on to form Nordic Lexel Group in 1995 when it merged with the NKT Group of Denmark.

Norwesco

Norwesco AS (Skårer) was established around 1910. The firm currently has 64 employees and a turnover of 110 million NOK (1998). The firm has had a very similar product portfolio to that of Elektrokontakt. The firm has developed and designed and produced its own line of electrical accessories, and has collaborated closely with electricians, installers and consultants in the ongoing innovation process. The main market for the firm is Norway, and 55% of sales are originates in its own production plant. The remaining is produced elsewhere.

In the same manner as Elektrokontakt, Norwesco was brought into the Lexel Group and recently into Schneider Electric. This has had important effects on the firm and its strategy. Development and design is being moved out, to Lexel R&D facilities abroad. At the same time, some of the core products of Norwesco is now being produced and marketed across the Nordic region under the Lexel brand name. Similarly, some of the products that earlier were manufactured at the Norwesco plant in Skårer are now being produced and distributed from the other Nordic countries.

Beyond this, Norwesco strives to establish itself in the emerging markets for technologically advanced products and integrated solutions that rapidly are becoming standard feature of modern buildings. New systems products such as Norwesco DataConnect (NDC) and advanced control products.

The fact that Norwesco is part of Schneider Electric is very important for the strategy in these emerging markets. Through the coupling to the larger corporate organisation, the firm is part of a corporate structure which is capable of carrying through the very costly development of these advanced systems products, and it has access to the know-how and the financial resources that are needed to deliver such systems to customers.

The Lexel Group

Lexel is an international group with its head office in Copenhagen. Sales and production takes place in 18 countries. Net sales amount to more than 4 billion DKK, and the group has more almost 6000 employees. Lexel aims at being a first tier technology company, and a European full house supplier of electrical installation material, installation systems for power, telecommunications and data, and control & communication network systems of all types.

Given that electronics and computer technology are playing an increasing role in installations, both commercial and private, Lexel aimed at exploiting collaboration effects across national borders to develop sufficient strength in this field to be internationally competitive. The companies of the Lexel Group are intended to draw on the corporate structure to get access to first-class R&D, designers, market analysts, planners, management and production teams, "just as if they were on its local staff". The firm's electronic product line comprises components ranging from dimmers, timers, thermostats and data installations material. When developing complete product families, the idea is to

focus on the most technologically advanced product with the greatest degree of functionality available within the group. The broader product line is then developed with this leading product as "template".

Schneider Electric

On January 1, 1999, Lexel was acquired by the French Schneider Electric. Schneider is a global actor focused on electrical distribution and on industrial control and automation. For the financial year of 1998, Schneider Electric's net sales amounted to 50 billion French francs. Schneider has its headquarters in Paris and operates in 130 countries. The number of employees is 61,000

The management of Schneider predicts that while there were 300 global market segments ten years ago and there were 1,500 in 1995, by the year 2000, there will be 6,000 or 7,000, and five companies in the world control 80% of the market. Schneider's strategy is to be global and local at the same time, with the ability to respond to each customer's specific needs.

Sources: Interviews with managers, material from web sites of respective firms, Lexel Group annual report 1998.

Eldrive AS was founded as Sigma Elektroteknisk AS in 1947. Sigma developed advanced control units for electric fork lifts. After being acquired by ABB in 1991, the firm was spun off again as an independent firm in 1996, with the name Eldrive AS. The firm currently has a stock of 16 employees, of which the development group makes up one third (5 people). The core motor control technology from the Sigma Elektroteknisk era remained with ABB, and the Eldrive currently has its key focus in the business of making intelligent charging equipment for batteries used to run electric vehicles. This is a development business which has as much to do with computing and programming as it has to do with conventional electro-technical development. The main product of the firm is an "intelligent" charging unit which performs optimised charging of batteries based on a large number of environment and performance variables. The charging is steered by a computer running software developed in-house. This software adjusts charging cycles according to temperature, utilization cycles of batteries, the cost of keeping batteries out of productive work, etc.

The firm is knowledge intensive business, and it is in the design and tailoring of the charging unit that most of the development costs are sunk. The actual production of the unit is simple and straight forward.

In line with its technological and product niche strategy, the firm has established a strategic partnership with one of the largest battery manufacturing firms in the world (Hoppeke of Germany) and aims at growing by becoming the preferred partner of this firm also in other markets than the Norwegian.

The competence base of the firm is found in-house, and is developed in close interaction with its customers. There is very little or no collaboration with external research milieus, and the reasons given in our interview with one of the employees are mainly focusing on costs, collaboration difficulties and the problem of finding the necessary match in competence and interests.

Collaboration with external researchers is demanding in resource terms. The firm has few employees, busy in the day to day running of the business. Manpower cannot be put on the task of pursuing development work together with external partners who are not adequately focused on the specific technological issues that are crucial for the business. Furthermore, collaboration is difficult because of a cultural distance: Researchers in research milieus do not seem to have the kind of commitment to solve specific problems within given time and resource boundaries that people in business R&D have.

The firm's is currently owned by its president and Narvik Technology.

Source: Interview with employee and material from <http://www.eldrive.no/>

The technically oriented firms producing equipment, accessories and technical solutions mainly for the professional market much in the same way as electronics firms are faced with globalisation tendencies. Firms in general are technology based, which means that they are also fundamentally knowledge intensive. For a small or medium sized firm there is often a need to make a rather risky choice of technological and market niche, where the knowledge intensity can be of such a quality that the firm stands out as an attractive partner for other firms to outsource parts of the value creation effort that their business encompasses (outsourcing/subcontracting). Small firms may find large collaborating firms may give them leverage and open up new markets which they would not have managed to get into alone. At the same time, large firms can relatively easily appropriate key technologies from small, avant-garde firms.

The trend to develop large corporate structures, and towards globalisation, must ultimately be understood as a way to secure the logic of one particular innovation system. By linking up firms in larger structures, one manages to ripe scale benefits, while at the same time making sure that technological developments in all relevant dimensions of technological systems add up to a functioning whole. Thus, on the one side, the linking of electrotechnical firms may make it possible for local producers to sustain operations and product development, while at the same time to secure market position by functionally “dividing” market between units within the larger corporate structure. On the other hand, the linking of firms make possible the advance of complex technological systems, by way of harmonising diverse technologies and by integrating them in hitherto unseen complexes of functionality.

5.4. Multinational firms producing consumer durables

Electrolux Norge AS

The Electrolux company has grown from being established as a small Swedish producer of vacuum cleaners in 1919 into becoming the worlds largest producer of household appliances. Electrolux Norge was established as a sales company in 1960.

The company acquired the *Electra* factory at Bøn near Eidsvoll, from Per Kure AS, a producer of electric cookers since 1911.

Today, 40% of all electric cookers sold in Norway come from Electrolux at Bøn, while the remaining volume is exported.

Electrolux has invested several millions in modern production equipment and machinery at the factory, and continous product development has led the factory to have a leading position in the Norwegian market, and a strong export business.

The factory is currently the biggest electric cooker factory in Norway, with 190 employees. The firm boasts a local construction and development division, however, the company is closely integrated in a larger European production and innovation system, and is subjected to central coordination with respect to overall strategy, marketing and and purchasing of the global Electrolux corporation. Also design and product development is to a large extent going on in centralised locations. The uniform design of product lines from diverse factories, and the fact that the factory in reality has only four (4) very large customers, obviously reduces the freedom of the local organisation to carry through innovations.

Source: Interview with manager, and material from <http://www.electrolux.no/>

Luxo ASA is a leading, international manufacturer and marketer of lighting solutions. The firm's shares are traded at the Oslo Stock Exchange. LUXO advertises its business idea as being an international and profitable leader in serving the need for ergonomically correct lighting solutions that are positive for the work environment in the market segment of modern offices, industry and health care, by developing, manufacturing and marketing environment-friendly quality lighting with a good, functional design.

Luxo distinguishes between its project sales and its over-the-counter sales of lighting equipment. In the first case, products end up with electricians and installers engaged in building projects, and Luxo is increasingly collaborating with architects and builders to develop high quality lighting solutions.

At the same time, the company maintains a product line of lamps aimed both at specialised professional customers, and at the broad consumer market.

The firm has 520 employees, of which 130 in Norway. The head office is in Oslo, the main Norwegian production facility is in Kirkenær, in Hedmark.

Luxo has production operations also near Borås in Sweden, manufactures design products near Bergamo in Italy, has assembly operations in Australia and the US, and produces specialty medical lighting equipment in the US.

About 8 designers and product developers work in the Oslo facilities, among them several engineers, people expert in reflector technology, advanced materials and production technology.

Luxo primarily relies on internal competence for development of products. There is some use of external designers, but little use of external research institutions.

Source: Interview with employee and material from <http://www.luxo.com/>

As indicated by the Electrolux example, the globalisation is an ongoing process that has also affected strongly the consumer durables segment of the electrotechnical industry. The example of electric stove production shows both the attractions and the negatives of becoming integrated into multinational corporate structures. On the one hand, employment may be secured, and good products may be coming out of the plant. On the other hand, the freedom of the individual firm to innovate and to design its own line of products is very much reduced, and the strategic center of the organisation can be moved far away from the Oslo region, and out of Norway. However, as the Luxo example shows, also in this industry segment, focusing on a rather narrow niche of technology and of markets may make it possible to operate successfully on a "narrow, global band". Building on a carefully developed knowledge base, and on a well defined business idea, niche producers may very well go on working along side the huge multinational corporations.

5.5. Policy considerations

As in the electronics industry, the dynamics of the electrotechnical industry is created by the joint working of technology, entrepreneurship, finance and regulation.

There is significant technology development activity. There are sustained efforts in small firms to develop new avant-garde solutions taking new ideas and concepts, design principles and materials as building blocks. The integration of electronics, computing and electrotechnical technology is an important trend with significant consequences both for small firms, and for the ongoing process of developing large business organisations across national borders.

There are intense economic forces of financial nature shaping the developments of firms and technologies, but probably somewhat different in their workings from what we see in the electronics industry.

Finance tend to be more closely connected to business development activity in the electrotechnical industry, and appears to be less of an independent force driven by speculation. The captains restructuring the electrotechnical industry are both industrial and financial capitalists.

Finally, there is no doubt that significant and consequential efforts going on government and regulatory level in order to promote and – in some extent – to shape the future development of the electrotechnical industry, both nationally and globally. The drive towards liberalisation of trade is very important in its consequences. Furthermore, regulatory innovations – often motivated by concerns for the environment and for the prospect of sustainable development – puts down very important premises for the ongoing innovation processes in the industry.

Appendix 1: The categorization of technology firms: NACE codes

Category 1: “Machinery and machine tools”⁵³

- 29,11 Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
- 29,12 Manufacture of pumps and compressors
- 29,13 Manufacture of taps and valves
- 29,14 Manufacture of bearings, gears, gearing and driving elements
- 29,21 Manufacture of furnaces and furnace burners
- 29,22 Manufacture of lifting and handling equipment
- 29,23 Manufacture of non-domestic cooling and ventilation equipment
- 29,24 Manufacture of other general purpose machinery not elsewhere classified
- 29,31 Manufacture of agricultural tractors
- 29,32 Manufacture of other agricultural and forestry machinery
- 29,40 Manufacture of machine tools
- 29,51 Manufacture of machinery for metallurgy
- 29,52 Manufacture of machinery for mining, quarrying and construction
- 29,53 Manufacture of machinery for food, beverage and tobacco processing
- 29,54 Manufacture of machinery for textile, apparel and leather production
- 29,55 Manufacture of machinery for paper and paperboard production
- 29,56 Manufacture of other special purpose machinery not elsewhere classified
- 29,60 Manufacture of weapons and ammunition
- 29,72 Manufacture of non-electric domestic appliances

Category 2: “Electronics, computers, instruments and automation”⁵⁴

- 30,01 Manufacture of office machinery
- 30,02 Manufacture of computers and other information processing equipment
- 32,10 Manufacture of electronic valves and tubes and other electronic components
- 32,20 Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy
- 32,30 Manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods
- 33,20 Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
- 33,30 Manufacture of industrial process control equipment
- 33,40 Manufacture of optical instruments and photographic equipment
- 33,50 Manufacture of watches and clocks

Category 3: Electrotechnical

- 29,71 Manufacture of electric domestic appliances

⁵³ “29,71 Manufacture of electric domestic appliances” has been moved to category 3.

⁵⁴ The category “33,10 Manufacture of medical and surgical equipment and orthopaedic appliances” is *not* included here.

- 31,10 Manufacture of electric motors, generators and transformers
- 31,20 Manufacture of electricity distribution and control apparatus
- 31,30 Manufacture of insulated wire and cable
- 31,40 Manufacture of accumulators, primary cells and primary batteries
- 31,50 Manufacture of lighting equipment and electric lamps
- 31,61 Manufacture of electrical equipment for engines and vehicles not elsewhere classified
- 31,62 Manufacture of other electrical equipment not elsewhere classified

Category 4: “Vehicles, railway, aircraft, small boats”

- 34,10 Manufacture of motor vehicles
- 34,20 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
- 34,30 Manufacture of parts and accessories for motor vehicles and their engines
- 35,12 Building and repairing of pleasure and sporting boats
- 35,20 Manufacture of railway and tramway locomotives and rolling stock
- 35,30 Manufacture of aircraft and spacecraft
- 35,41 Manufacture of motorcycles
- 35,42 Manufacture of bicycles
- 35,43 Manufacture of invalid carriages
- 35,50 Manufacture of other transport equipment not elsewhere classified

Category 5: Offshore and shipbuilding

- 35,11 Building and repairing of ships and offshore installations etc.

Category 6: ICT services

- 72,10 Hardware consultancy
- 72,20 Software consultancy and supply
- 72,30 Data processing
- 72,40 Data base activities
- 72,50 Maintenance and repair of office, accounting and computing machinery
- 72,60 Other computer related activities

Appendix 2: Tables for illustrations.

Table A1: Firms by area and industry, percent (Fig. 2)

	North	East	South	West	Oslo	Total
Machinery, machine tools	36,5	29,2	29,6	6,3	13,8	16,2
Electronics, computers, instruments, automation	3,8	10,4	5,6	8,9	4,4	5,9
Electro-technical	21,2	20,8	14,1	9,9	8,2	10,9
Vehicles, railway, aircraft, leisure boats	11,5	9,4	9,9	6,3	2,4	4,9
Offshore, shipbuilding	0,0	1,0	2,8	4,2	1,9	2,2
ICT-Services	26,9	29,2	38,0	64,4	69,2	59,9
Total	100	100	100	100	100	100

Table A2: Employees by area and industry, percent (Fig 3)

	North	East	South	West	Oslo	Total
Machinery, machine tools	18,3	32,6	22,3	6,6	12,1	13,1
Electronics, computers, instruments, automation	1,2	10,4	2,5	30,7	10,9	14,1
Electro-technical	69,7	16,2	18,6	6,6	5,3	9,2
Vehicles, railway, aircraft, leisure boats	4,6	28,3	3,7	25,2	11,9	14,9
Offshore, shipbuilding	0,0	6,1	0,5	0,7	1,6	1,6
ICT-Services	6,2	6,4	52,4	30,2	58,1	47,0
Total	100	100	100	100	100	100

Part IV: Innovation and knowledge creation in the machinery and equipment industry in the Oslo region.

By Heidi Wiig Aslesen

Main findings

General findings

- The machinery and equipment industry is in decline in the Oslo region. The larger companies are moving out of the region, leaving many small heterogeneous companies.
- As many as 78% of the firms in machinery and equipment in the Oslo region have less than 10 employees. The largest concentration of firms is found in Oslo, which has 50% of the firms and 60% of the employees.
- The knowledge base that can be seen as common to all firms in the industry is linked to machine tools technology. The machine tool technology implemented in firms has varying levels of technological sophistication.
- In terms of the levels of technological sophistication, the industry in the region can be divided into two groups of firms, one group having low technological sophistication, and the other having high levels of technological sophistication.
- Internal training of employees has become an important activity for firms to undertake. One reason for this is that the level of formal education in the machinery and equipment industry in Oslo is relatively low. As many as 82% of the workforce have high school (upper secondary school) as their highest educational level achieved.
- The more traditional branches are facing problems related to a high average age in the workforce. One reason for this is a difficulty in attracting young people. Young people generally either have little knowledge of the industry, or the industry is unattractive to them.
- Natural sciences are the fundamental knowledge base of the machinery and equipment industry. There is a tendency among young people not to select technological- and natural science based educational subjects, both at high school level and at college or university level. As a result some parts of the industry already have difficulties in recruiting young people with the relevant education.
- Small firms find it difficult to use apprentices and students for project work within the firm, lacking both the time and the resources to pursue these opportunities.

- Few small firms employ engineers, as engineers are often perceived as being too expensive.
- Engineers are often found in more sophisticated firms. The engineers are educated either at regional colleges or at universities. Because of a shortage of relevant engineers in the region (or in Norway as a whole) some firms have employed engineers from abroad. Few engineers are attracted to more traditional firms for work, and this widens the gaps in competence and technology between the two groups of firms found in the region.

Technological trends

- A trend in the education system linked to the machinery and equipment industry is the development of subjects in the areas of manufacturing process/systems, data engineering, and computerised management of production activities. The move towards more sophisticated systems in all areas of industrial production creates an obvious need for underpinning knowledge.
- Investment in new production technology introduces companies to a range of new techniques, and therefore creates a demand for new updated knowledge.
- Changes in machine tool technology have had serious implications for firms, and have turned the industry into the most universal user of information technology and computer engineering.
- Knowledge of information technology (IT) is a prerequisite in most areas of the machinery and equipment industry. IT is increasingly the platform and interface for all production functions in the industry.
- IT-based training is of the utmost importance to the industry.

Findings on innovation

- The Community Innovation Survey for Norway has looked more closely into the innovation activity of the firms with more than 10 employees. The data shows that for this group of firms, machinery and equipment manufacturing is a relatively innovative industry. As many as 54% of these firms engaged in innovative activity in the period from 1995-1997.
- Innovation activity fluctuates a great deal according to company size. Among firms employing between 10-49 people, the percentage of innovative firms is 42% (meaning that 58% of these firms did not engage in any innovation activity). However, among firms with over 250 employees, 91% are innovators.
- Firms in the industry that employ 50-249 employees appear to be very dynamic. The proportion of innovative firms in this group exceeds the average for manufacturing by 25 percentage points.
- Innovation in the industry is led by 'demand pull'; firms have a strong market orientation in their product and process development. Two thirds of firms' innovation-related collaboration is with clients or customers. Customers are also one of the most important information sources for innovation. Finally, most of firms'

R&D activity is carried out internally and is closely linked to commercial specifications.

- Demand-led innovation strategies mean that companies in the industry do not view innovation from a long-term perspective. The shortage of links with R&D environments can be seen partly as a result of this short-sighted innovation strategy. Firms that do not take part in long-term R&D activities will be vulnerable in the long run.
- Skills and competence-building both in relation to management of machinery and in relation to information technology are an important part of firms' innovation activity. Close to 40% of firms with 10-49 employees have engaged in training linked to technological innovations. Training is an important factor for enabling firms to close the technological gap that exists within the industry, and to follow strict quality requirements such as ISO 9000.

Findings on the innovation system

- Few firms value the scientific community as a relevant information source.
- Relevant knowledge providers related to machine tools in the Oslo region are the Oslo-college, Lanbrukshøyskolen at Ås, University of Oslo and some parts of the Kjeller environment. Few firms have knowledge of the relevant activities that are carried out in these milieus, and they are often regarded as being somewhat 'closed'.
- There is a clear relationship between the size of firms and their use of the scientific community.
- Small firms (10-49 employees) have relatively low levels of innovation collaboration with knowledge providers such as consultancy firms, universities or research institutes. There seem to be few relevant knowledge providers in the region (besides the Technological Institute) that are geared towards firms of this size.
- Knowledge-supplying institutions that provide R&D often specialise in the most sophisticated techniques. The most utilised knowledge suppliers are in the SINTEF milieu.
- Relevant R&D institutions are directed towards technologically sophisticated and financially strong firms, and this network of relationships seems to function well.
- Small firms appear to be somewhat left out of these innovation networks. Cultural differences between firms and R&D institutions are a significant obstacle to collaboration. Small firms feel that their R&D needs are not taken seriously. When a firm's R&D projects are evaluated, R&D institutions often do not appreciate the importance of the project or they show little interest, unless the project is very sophisticated in nature. Small firms feel that the R&D institutions have an arrogant attitude towards their needs, and express a wish that the R&D milieu had more interest in the real needs of this part of the industry.
- The technologically strong firms that do find relevant R&D environments in the region (or in Norway) experience technology transfer from the scientific milieu

through new students and through students' projects and Master theses, as well as through general R&D.

Policy diagnosis

- In order to attract young educated people to the industry, students need to be informed about the industry and the opportunities it offers. Very few students actually know anything about this industry, and very few have had relatives working in the industry. The industry needs to market itself to a new generation, for instance through meeting points between industry and students (educational institutions).
- Such meeting points could also be used as a forum in which educational institutions could market themselves to regional industry. There is a need for industry to be kept informed of the ways in which relevant educational institutions can be of value for firms, for instance by offering apprentices and students for project work (hovedprosjekt). This kind of knowledge input would be of great value for many small firms.
- Meeting places between industry and educational institutions should not be limited to institutions in the region. There are, for instance, regional colleges in other counties that specialise in specific fields of relevance to Oslo-based industry, about whom it could be valuable for firms to learn.
- There seems to be a mismatch between the types of education and training offered in the region, and the needs of the industry. There should be incentives for small firms to forge networks through which they can map their common needs, and present them in unison to relevant regional authorities or institutions.
- There are examples of courses being offered by a regional college that were in response to demand from the industry, but in which very few participants enrolled. It is important to offer courses that firms' employees are able to attend; they cannot be too expensive, and they need to be short.
- Institutions that give courses should have the financial resources to complete all offered courses, even if very small numbers sign up to attend the course. Lack of resources should not be a valid reason for failing to cover the competence needed in the region.
- It is important to have high competence levels at the semi-public institutions to which firms go for training, testing, etc. These institutions, which are part of many firms' innovation networks, should have the financial ability to recruit the best people.
- Small firms cannot afford to employ engineers, and this makes the technological gap wider in the long run. There should be an initiative to encourage small firms with similar needs to hire, for instance, a single engineer who could be shared by three firms. Another solution would be for public authorities to come in and finance engineering work for a certain amount each year.
- Innovative firms have a need for ongoing R&D that is not market-led. Firms have great problems with getting finance for this kind of activity. This is not helped by the heterogeneity of firms in the region. These independent actors have little

power to 'lobby' for R&D schemes that are relevant to the industry. Networks between firms, with common effort to push for relevant industry-specific R&D schemes could be beneficial.

- The scientific community should be encouraged to respond better to those of the industry's R&D needs that are not at the forefront of technology.
- Relevant local faculties could be more proactive towards business in the region. They could open the way for firms to take part in lectures or seminars by informing them of their activities (for instance via continuous updates on their websites, informing of lectures and ongoing or forthcoming R&D projects).
- There needs to be lower entry criteria for existing innovation networks. Efforts should be made to link small firms up to innovation networks that already exist between the more sophisticated firms and the scientific communities, as much of the innovation activity here will also be of relevance to less sophisticated firms.
- Technology transfer should take place through institutions with which firms already have contact (e.g.ABR, Næringetatene in the County Council or Communities, and in particular Technological Institute).

1. Introduction⁵⁵

The machinery and equipment industry produces both consumer goods, and equipment for production that is used in almost all branches of industry. There are very few machine tool producers in Norway, so most firms buy equipment from foreign suppliers and adjust the machinery to suit their needs. Industrial activity in this Norwegian sub-contracting sector has a core supply function to important industries such as shipbuilding, parts of petroleum production, fisheries, and hydro-energy production. Many machinery and equipment firms are so tightly linked to their customers that they feel closer to the customers' industry, rather than to the machinery and equipment industry itself.

The sector also produces inputs for its own production. The means of production in the industry is machinery of various kinds. There is no clear-cut difference between machinery and equipment production and other sectors that use mechanical engineering technology. The overlap between these sectors is profound, making it difficult to arrive at a clear cut definition of the industry. Many sectors - such as manufacture of metal products, and transport equipment - are heavy users and producers of machinery and equipment, and tend to employ the same basic technological knowledge in their production, namely mechanical engineering, electronics and materials technology.

Historically, the machinery and equipment industry has been important to Norway's development. This industry has, since the beginning of the 19th century, been an intermediary for important parts of the technology on which the development of Norwegian society and the prosperity of modern Norway has been founded⁵⁶. The industry developed largely through technology transfer, by imitating larger, technologically advanced nations. Technological capacity developed in the dynamic industrial leading economies - in the 19th century this meant Great Britain and Germany specifically - was imported to Norway. Continual competence-building in the machinery and equipment industry was important in that the industry became geared towards problem-solving. Technical competence was, and still is, of major importance. In the early days of the industry, technology transfer was a complicated business, involving travel, education, acquisition of work experience from abroad, acquisition of foreign machinery (and even foreign workers), and broad contacts with similar industries abroad.⁵⁷

The industry has been particularly important in the Oslo region, with large firms supplying shipbuilders and later oil-platform builders in the region. However, there has been a radical structural change in employment in the machinery sector since 1970. As an interviewed labour union representative said: "In the 70's and 80's there

⁵⁵ Parts of this report have been taken from work carried out by Trond Einar Pedersen "Machinery, equipment and machine tool technology in Norway: mapping the technology knowledge bases".

⁵⁶ Even Lange, 1989. "Industrien bak det moderne Norge", page 11, in; Even Lange (eds.), 1989. "Teknologi i virksomhet. Verkstedsindustrien i Norge etter 1840", page 11. Ad Notam forlag AS.

⁵⁷ Kristine Bruland, 1989. "Teknologioverføring 1840-1900", pages 72-73, in: Even Lange (eds.), 1989. "Teknologi i virksomhet. Verkstedsindustrien i Norge etter 1840". Ad Notam forlag AS.

where 7 or 8 companies employing more than 1000 people in the region; today there are only 2 companies that employ more than 200". The relative strength in employment terms of the Oslo area in the early 1970s has diminished in the last two decades (while it has also diminished in absolute terms), and Western Norway has taken over as the industry's main employer since the 1980s. Above all this change is a result of the strong growth in petroleum-related machinery production in Norway. The northern part of Norway has only marginal employment in the sector. In southern Norway, the sector is still relatively strong on the west coast, and the industry is relatively large in central parts of the country in particular. This region broadly speaking covers the counties of Buskerud and Oppland, in which the area around the town of Kongsberg is by far the most significant for the industry. The industrial environment in Kongsberg today contains several major Norwegian industrial players such as Kongsberg Gruppen AS and Norsk Jetmotor AS. In addition there are a number of highly competent sub-contracting companies, both in manufacturing and in engineering consultancy services.

The machinery and equipment industry is currently undergoing a turbulent period, and uncertainty prevails in the industry. However, as one interviewee said: "This industry has always been a sub-contracting sector, making it dependent on the ups and downs of the market. The industry has always needed to adjust to changes. The most important ingredient for firms' ability to adjust in the industry is their ability to learn. The challenge lies in making firms understand that this also applies to *them*. In a period of recession, innovation and learning are the most important activities that firms should engage in, in order to raise the competence and quality level of the firm."

Who then represents the machinery and equipment industry in the Oslo region today, what do they produce, and how do they perform in economic terms? The next section will present some background statistics on the industry.

1.1 Employment and number of firms in the region

In 1996 there were registered 167 firms in 'manufacture of machinery and equipment' in the Oslo region, and we know that by the time of writing the number is even smaller. The table below shows the distribution of these firms according to numbers of employees.

Table 1. Number of firms in manufacturing of machinery and equipment in the Oslo region, by size (number of employees). Source: SSBs employment register, 1996.

<i>Size groups</i>	<i>Number of firms</i>	<i>Percentage of firms</i>
1	44	26%
2-5	65	39%
6-9	21	13%
10-19	16	10%
20-49	8	5%
50-99	7	4%
100-249	5	3%
250-	1	0%
Total	167	100%

The table shows that the largest proportion of firms have between 2 and 5 employees; this category accounts for as many as 39% of the registered firms, suggesting that the industry is dominated by small firms. 78% of the firms in the region have under 10 employees. The indications of these statistics were confirmed in interviews. Most of the larger players in machinery and equipment have moved out of the region, leaving a heterogeneous collection of small firms. The level of technological development, or sophistication, of these remaining firms is extremely diverse. Many firms act mainly as service providers, repairing and machining for other firms in the region, and are therefore strongly dependent on these technology-using firms. One interviewee in particular did not see this as a problem. Technology-based firms will always need such services, but the service-providing firms' role may change in that they become service entities in a much broader sense, closely linked to their major customers. The challenge for the region in this context is to keep the relatively large 'technology firms' within the region. The machinery and equipment industry in the Oslo region consists mainly of a group what we would traditionally call 'service' firms, providing the more technologically advanced firms with input into their production of machinery and equipment.

Table 2. Location of firms in manufacturing of machinery and equipment in the Oslo region. Source: SSBs employment register, 1996.

<i>Location in the Oslo region</i>	<i>Number of firms</i>	<i>Percentage of firms</i>	<i>Number of employees</i>	<i>Percentage of employees</i>
North ⁵⁸	21	13%	126	5%
Oslo	83	50%	1584	60%
South ⁵⁹	21	13%	237	9%
West ⁶⁰	12	7%	268	10%
East ⁶¹	30	18%	439	17%
Total	167	100%	2654	100%

In 1996, the machinery and equipment industry employed 2,654 people in the Oslo region. These employees were found in 167 firms, making an average of 16 employees per firm. Where in the Oslo region are the firms located, and are there differences in the size of firms in different areas? The table above shows that 50% of the firms, and 60% of all the region's employees in machinery and equipment, were located in Oslo; the area also has an average firm size slightly above the average for the region as a whole. The eastern part of the region has the second largest concentration of firms and employees, with 18% of the firms and 17% of the workers. The northern and southern parts of the region have 13% of the registered firms each; these firms are relatively small, accounting for 5% and 9% of employment respectively. In the western part of the region, there are few registered firms in machinery and equipment (12 firms, 7% of the total), but they do seem relatively large (10% of employees).

1.2 Economic performance of the machinery and equipment industry

In order to place the machinery and equipment industry in context, we will present some key numbers for the industry, both for the country as a whole and for the Oslo region. The industry is heterogeneous, so the data will be presented according to sub-groups within the industry.

⁵⁸ Nittedal, Nannestad, Hurdal, Eidsvoll, Nes, Ullensaker, Gjerdrum.

⁵⁹ Vestby, Ski, Ås, Frogn, Nesodden, Oppegård.

⁶⁰ Asker, Bærum

⁶¹ Aurskog-Høland, Sørums, Fet, Rælingen, Enebakk, Lørenskog, Skedsmo.

Table 3. Key numbers for manufacturing industry, and for machinery and equipment, 1996. Numbers in brackets for the Oslo region. Source; SSB, Manufacturing statistics 1996.⁶²

Indicator	The machinery and equipment industry	Total manufacturing	% of total manufacturing
Number of firms	1164 (144)	11019 (2027)	10.56 (7.10)
Employment	22867 (2963)	281947 (44270)	8.11 (6.69)
Sales (mill. NOK) ¹	26236 (3209)	390959 (61214)	6.7 (5.24)
Value added (mill. NOK) ²	8418 (753)	115565 (23427)	7.28 (3.21)
Investment (mill. NOK) ³	462 (-18)	17593 (1745)	2.62 (-1.03)

Notes:

¹As sales figures are considered confidential we have to use *gross value of production* as an approximation. For indicators provided by the Manufacturing Statistics 1996 (sales, value-added, investment), all values are based on all firms, including firms with 10 employees and less.

² Defined at market prices and equal to gross value of production less costs of goods and services consumed, excluding VAT.

³ *Gross fixed capital formation*, defined as acquisition of fixed durable assets, new and used, with an expected productive life of more than one year, less receipts from sales of fixed durable assets.

Machinery and equipment firms make up just over 7% of the total number of manufacturing firms in the Oslo region, and about the same portion of the employment (6.69%). The proportions of firms and employment accounted for by this industry in the Oslo region are slightly lower than the corresponding proportions at a national level. Firms located in the Oslo region are larger than firms elsewhere in Norway. In terms of value added, the machinery and equipment sector in the Oslo region has a lower share of total manufacturing than the national average. Looking at the industry's share of manufacturing investment, the figure for the country as a whole is 2.62% while for the Oslo region the figure is negative, -1.03%, meaning that firms in the region have sold more durable assets than they have bought.

⁶² There is a difference in the registration of employees and firms between SSBs employment register and the manufacturing statistics. Reasons for this could be differences in the time of sampling, differences in registrations of employees. There has been a change in firm registration from 1995 to 1996; this may also have led to different practises for the two data sources.

Table 4. Key numbers in the Norwegian machinery and equipment sector, 1996.

Numbers in brackets for the Oslo region. Source: SSB Manufacturing statistics 1996.

Nace		Number of firms	Employment	Sales (mill. NOK)	Value added (mill. NOK)	Investment (mill. NOK)
29	Machinery and equipment	1164 (144)	22867 (2963)	26236 (3209)	8418 (753)	462 (-18)
29.1	Mechanical power machinery	156 (22)	5,381 (471)	7,661 (1459)	2,268 (102)	-109 (-70)
29.2	Other general purpose machinery	482 (64)	7,345 (249)	8,308 (701)	2,523 (259)	206 (14)
29.3	Agricultural and forestry machinery	167 (5)	2,107 n.a.	2,016 na.	742 na.	30 na.
29.4	Machine tools	42 (6)	517 na.	368 na.	185 na.	32 na.
29.5	Other special purpose machinery	279 (40)	4,154 (179)	4,683 (723)	1,502 (268)	123 (28)
29.6	Weapons and ammunition	9 (1)	2,123 na.	2,093 na.	764 na.	152 na.
29.7	Domestic el. and non-el. appliances	29 (6)	1,240 na.	1,107 na.	434 na.	28 na.

Because the machinery and equipment industry is heterogeneous, Statistics Norway (SSB) has 7 sub-classification categories within the industry. In order to understand this industry in a regional context, it is important to see which sub-sectors are the most significant in the economy. The table above gives an overview of these categories, showing their relative importance in terms of firms, employment, sales, value added and investment. According to these figures, the largest groups are 'mechanical power machinery', 'other general purpose machinery' and 'other special purpose machinery'.

The industry's 2,963 employees work in the manufacture of engines and turbines (excluding aircraft, vehicles and cycle engines), pumps and compressors, taps and valves, bearings, gears, gearing and driving elements, furnaces and furnace burners, lifting and handling equipment, non-domestic cooling and ventilation systems, and finally the general areas of manufacture of 'other general and special purpose machinery'. The mechanical power machinery segment of the industry seems to be experiencing severe difficulties: in 1996, negative investment in this area amounted to -70 mill. NOK.

1.3 Main technological trends in the industry. The role of IT.

A trend in education linked to the machinery and equipment industry is the development of subjects in the areas of manufacturing process/systems, data engineering, and computerised management of production activities. The relative importance of these subjects is increasing in line with the development of new production technologies. Although this has not affected the importance of traditional subjects, the move towards more sophisticated systems in all functions of industrial production - along with the general acquisition of new machine tools - creates an obvious need for underpinning knowledge. One example of this is the demand for engineers who have advanced competence both within traditional engineering and crafts, and within information technology (IT). Having said this, the industry's most

obvious needs for up-to-date knowledge do seem to be catered for by the education system, at least at a general level.

Competence in information technology (IT) is worth mentioning explicitly as a prerequisite for most areas related to this industry. Educational institutions employ computers and software tools in all aspects of education; external consultancy competence is based on software products, and IT is increasingly the platform and interface for all industrial production functions.

Table 5. Technologies in the machine tool industry 1975-1990.

Technologies in the machine tool industry 1975-1990								
	Solid mechanics	Machine design (gearing)	Machine design (bearing)	Engineering materials	Control engineering a	Software engineering a	System engineering b	Computer communication b
Conv.lathe, 1975	X	X	X	X				
CNC lathe, 1975	X		X	X	X	X		
FMS, 1990	X		X	X	X	X	X	X

a) Includes knowledge of drivers, sensors and electronics
b) Application specific knowledge is a prerequisite for good system engineering
Source: From Paper 1a in Ehrnberg 1996, Technological Discontinuities and Industrial Dynamics.
Based on an interview with Professor Nils Mårtensson, Chalmers Univ. of Technology (July 1991)

The table above charts the progression in the machine tools sector from conventional (manually worked) machine tools to CNC (Computer Numerical Control) machines, and from stand-alone CNC machine tools to flexible manufacturing systems (FMS). As the table indicates, in addition to the necessary investment in hardware (machine tools), investment in new production technology implies the introduction of a range of new techniques, and therefore creates a demand for new up-to-date knowledge. Operation of stand-alone CNC machine tools requires basic knowledge of machining as well as electronics and software/computer engineering. Production using machine tools in networks is triggering a more comprehensive need for control and system engineering. The most recent trend is the utilisation of direct PC-communication with the tools.

Changes in machine tool technology have serious implications for firms. In the transition from manually worked and conventionally controlled stand-alone machine tools towards the implementation of FMS, there is a need for more or less comprehensive restructuring of production routines, production surveillance, internal logistics and quality control. This has made mechanical engineering industries and machinery and equipment production into perhaps the most universal users of information technology and computer engineering. Data-assisted design, construction and production, quality concepts, and productivity management are areas in which all kinds of information technology are exploited.

For obvious reasons the acquisition of advanced machine tool technology is not equally distributed across firms. In this respect firms vary according to age, activity, size, organisation, financial strength and production strategy. It seems that although an industry is 'mature', the technology in use is often sophisticated, and in these industries there is often a broad mix of old and new machines. Firms might have

manually worked machines alongside data-assisted tools with 3-D design, this being the 'latest' technology in the industry.

IT has a role to play in all competence areas of the industry, and has become an integral part of production in most firms. IT is a basic element of firm-specific knowledge, and performance is often dependent on the firm's level of sophistication and technological competence.

1.4 Further outline of the report

In part two of this report we will examine the knowledge base of the industry. We will attempt to map the relevant knowledge-providing institutions that firms can approach with their R&D needs, and the kinds of institutions that make up the organisational support for this industry. In part three we will analyse the competence-level of employees in machinery and equipment, and try to pinpoint the kinds of skills and training schemes that are needed in the industry. One important question here is whether the industry is able to find qualified workers in the region.

Section four examines innovation in machinery and equipment; we will present data on the ways in which innovation is carried out in this particular industry, and then try to find the important 'ingredients' of innovation and highlight the particular innovation needs of the machinery and equipment industry. We will explore firms' networks of relationships, by looking at who they innovate with, and who they regard as important information providers for innovation. An important aim of this research will be to identify the most important knowledge suppliers to this industry, along with their locations, and the degree to which they are geared towards SMEs. Section five will summarise our findings.

2. The knowledge base of the industry and networks of relationships

This section aims to map the knowledge base of the machinery and equipment sector. A core technological activity in production of machinery and equipment is the operation of machine tools, in particular the treatment of metal components. It is the process aspects of production in machinery and equipment firms that have the greatest potential for development. For this reason is interesting to focus on production techniques when analysing the machinery and equipment sector, that is, machine tools. The majority of product groups related to the production of machinery and equipment involve input in the form of raw materials or semi-manufactures (metals), and the utilisation of machine tools (machining). Manufacturing activities range from manual work with smaller handheld machine tools and manually controlled single-task production, to computer controlled multitask and automated manufacturing systems with larger machine tools and machine tool systems; all of these fall within the domain of machining, construction and composition of metal components. Products are often integrated with electronic components, electrical or fuel-driven devices, and supported or driven by hydraulics or pneumatics.

Our point of departure in mapping knowledge bases for the machinery and equipment industry is the technological competence around machine tool technology. Innovation in machine tool technology is dependent on technological knowledge and competence in the use of machine tools in production; so the knowledge system

surrounding machine tools is important, not only of the Oslo region but in the whole of Norway (relevant institutions in the Oslo region are in bold in the table). Firms are not limited by the institutions in the region in their search for knowledge. A study of the technological knowledge bases underpinning the production of machinery and equipment is to some extent a study of knowledge and competence that is relevant across industrial sectors and across many activities, particularly in large firms.

Several knowledge inputs go into an industry, and the key knowledge resources that go into that industry can be described as the knowledge base from which it draws its competence. Mapping all the relevant knowledge bases of an industry is a complex task, as apparently simple industries can contain quite different and sophisticated knowledge bases derived from a wide variety of institutional sources. For instance, if a firm is to be a supplier of machinery and equipment to the food industry, that firm must have extensive knowledge of food production, and this adds several new technological fields to the knowledge base within the firm. In this study we will not take into account these knowledge bases needed by firms in order to serve specific clients; we will look simply at the key activities, techniques and corresponding scientific knowledge bases required for manufacture of machinery and equipment *per se*.

Table 6. Key activities, techniques, knowledge bases and knowledge institutions related to machinery and equipment.⁶³

Key activity	Technique	Knowledge base	Knowledge institution
Product development	Manual drawing and construction Computer aided 2/3D design Reverse engineering Rapid prototyping Computer aided construction Integrated product development Computer programming	Technical drawing Design engineering Engineering Cybernetics Basic electrical engineering Material properties	<u>Universities</u> UiO, UiTØ UiB, NTNU <u>Technical high schools/ Regional engineering college</u> HiT HiB HiG HiN HiNT Hi-Oslo HiS-MMT HiBu HsH HiT HVE HiØ HiÅ HiST HiAls STF Den Polytekniske høyskolen Hærens ingeniørhøyskole Landbrukshøyskolen på Ås (NLH)
Process development Process control	Manual process control Computerised process control Automated systems/ FMS Computer programming	Casting technology Welding technology Industrial electronics Machine tool design Mechatronics Servo mechanisms Control engineering Transport design Computer based controls of manufacturing processes	<u>R&D</u> RF NTNU SINTEF MARINTEK IFE
Manufacturing Machining	Manual welding, casting, cutting, moulding, lathing, etc. Semi-automated welding, casting, cutting, moulding, bending, etc. Automated welding, casting, cutting, moulding, etc. Computer programming	Mechanical engineering Production engineering Process engineering Manufacturing system theory Construction engineering Machine engineering Robot engineering Materials properties engineering	
Surface treatment		Surface engineering	
Quality control	Manual quality assessment and control Automated quality assessment and control Computer programming	Quality engineering	

The map is by no means comprehensive, but it does display the most important components in the knowledge system. The different techniques listed are often difficult to separate from the key activities, as many are interlinked.

For the majority of the listed knowledge bases, basic scientific subjects like physics, chemistry, mathematics, electronics, and mechanics are a precondition.

Competencies in information technology (IT) is worth mentioning explicitly, as it is a prerequisite for most knowledge areas.

The framework of technological knowledge underpinning production activities in the machinery and equipment sector encompasses several institutional arenas. Technical education provides the industry with basic as well as advanced knowledge, and is one of the most important foundations on which activity and development in the sector is based. There are two main ways in which the industry takes advantage of the education system: through the recruitment of personnel, and through knowledge-flow from certain kinds of links and co-operation with students. Some parts of the

education system perform R&D and have links to industry through R&D projects. The most relevant educational institution in the Oslo region is the Oslo College Engineering faculty. For the time being little research is carried out here, but there are ongoing plans for R&D projects and collaboration with IFE at Kjeller.

In addition to the regional technical colleges, faculties and institutes like NTNU and SINTEF provide Norwegian industry with advanced knowledge of machining technologies. This is certainly one of the most important sources from which industry accesses sophisticated scientific, engineering and technological knowledge. NTNU operates at a high level in terms of its technological sophistication, for instance in its focus on 3-dimensional (3D) design as a basic area of development. This may lead to higher entry barriers for small firms with conventional technology, as only larger firms with substantial resources and high levels of technological competence have the opportunity to use these institutions. This will tend to exaggerate further the gap between 'high' and 'low' technology within the sector.

Research and development funded with public money is performed through a number of institutional bodies, mainly within the education system. Advanced education of engineers is science- and research-based, and is conducted both on a theoretical level and through links to the industry. Students' projects and Master's theses are often concerned with specific issues of relevance and interest to local industry. A typical process of co-operation between industry and R&D environment might begin with a problem definition by a firm. The firm's proposal will then go through a stage of theoretical assessment and adjustment by the R&D institution, before being launched as a project proposal, fronted by the firm, to the Research Council (NFR) or other channels of public R&D finance. The typical Ph.D. thesis is undertaken in close relation to industry-specific problems, often by students who have already worked for some time at a firm in the industry.

In the NTNU/SINTEF education framework⁶⁴, R&D activities relating to machinery and production technique focus on the whole process of product development. All aspects - product and process development, production hardware, logistics, and product strategy - are taken into consideration. The basic framework tools which make this possible are data-assisted tools with focus on 3D design. 3D design enables analyses, adjustments and modifications to be made during early phases of development that would previously have been costly and time-consuming. 3D design is also argued to be very cost-efficient in later stages like marketing and assessment. However, for the industry itself, the associated costs and the required competence levels of this technology are high. For a small or medium sized firm with relatively conventional manufacturing processes, 3D is not the first concept likely to be considered when planning possible development. This focus on 3D design as a central part of the development process is therefore limited to large, financially strong firms that already have sophisticated production systems. SMEs may not have the necessary financial resources, nor a strategic interest in pursuing this technology.

The public R&D environment, at least in the NTNU/SINTEF departments, seems to co-operate mainly with the technologically sophisticated and financially strong part

⁶⁴ We are especially thinking of SINTEF Industrial Management, Dep. of production engineering, which is the part of NTNU/SINTEF with the general machinery and equipment production relevant R&D. Other parts of NTNU/SINTEF perform R&D activities with relevance for specific industries. We have chosen to focus on SINTEF Industrial Management, Dep. of production engineering.

of the industry, dominated by the giants of Norwegian manufacturing, mostly entities that are engaged in a wide range of industrial activities not limited to machinery and equipment. On the one hand, these institutions clearly conduct R&D activities from which small firms will benefit greatly, particularly in the more general fields. On the other hand there does seem to be very little contact between small, traditional firms and this R&D milieu. An example of an important potential side-benefit for small firms in establishing contact with these institutions would be the valuable help they would receive in writing financing proposals for potential R&D projects. Small firms have little knowledge or experience of how to apply for funding for R&D, or of the financing channels that are available.

Other external competence infrastructure

Other main actors, that seems to even more important to firms daily activities, include publicly supported institutions, e.g., Technological Institute (TI). TI is a total supplier within training in traditional crafts as well as in all kinds of newer production technique areas. TI seems so play an very important role in firms knowledge creation in the region.

As there are no manufacturers of larger machine tools in Norway, domestic industries are dependent on the procurements of Norwegian traders, or on imports from international companies. Some firms specialise only in larger machine tools, while others have diversified product portfolios spanning everything from industrial clothing, hobby articles and various hardware components, to handheld and larger machine tools. These differences in firms' product portfolios may explain strategic differences in the provision of knowledge-intensive services surrounding the delivery of the machine tools. Firms with a concerted strategy of procuring only larger machine tools tend to offer a more complete service, given the customer's greater potential need for knowledge. In terms of the organisation of the firm, this kind of focused strategy requires the purposeful selection of competent staff, and continuous attention to training and skills-development. Firms with a diversified strategy of selling all kinds of tools and equipment often ignore the service aspects. However, the firms that do have strategies of providing knowledge-intensive services integrated with the machine tools also vary according to the levels of service they provide. Some firms limit the services they offer to only those services which are most necessary, such as installation and test running.

Others have more comprehensive service organisations, offering knowledge based on advanced techniques, product development competence and human experience in the whole process of investing in machine tools for producing new products or increasing productivity. For the 'serious' firms, a comprehensive service strategy involves purposeful activity in terms of monitoring global technological innovations as well as user knowledge, operation, maintenance and service capabilities. This monitoring process is mainly directed towards international manufacturers of machine tools. Such firms innovate continuously in machine tool technology, and these innovations have potential implications for local firms' development. All large international manufacturers of machine tools conduct organised training and skills-development activities in connection to their product portfolio, and all serious traders in machine tools seem to have undergone this kind of training – and therefor are the most important knowledge providers to firms innovation activity.

3. Competence and training among workers in machinery and equipment

In this section we will focus on the educational backgrounds of employees in the machinery and equipment industry. We will then analyse further the educational backgrounds found in the industry, and the challenges that firms in the Oslo region face in this area.

Table 7. Relative shares of educational groups, Oslo region⁶⁵. Source: SSBs employment register, 1996.

<i>Educational group</i>	<i>High-school (1-12 years)</i>	<i>Univ. I (13-14 years)</i>	<i>Univ. II (15-16 years)</i>	<i>Univ. III (17+ years)</i>
Machinery and Equipment	82 %	8 %	4 %	6 %
All sectors	65 %	15 %	12 %	8 %

The table above distributes employees in machinery and equipment into four different educational groups, based on their highest level of formal education. This distribution of workers' highest achieved educational level is used as an indicator of formal competence in an industry. In 1996, as many as 82% of employees in the machinery and equipment sector had 'high-school' as their highest education level. This proportion is 17% higher in the machinery and equipment industry than the average for all sectors. This means that the machinery and equipment industry in the Oslo region has a relatively high proportion of employees with low levels of formal education.

The current uncertainty in the machinery and equipment industry, which is related to the offshore industry, is reflected in the subjects that young people are choosing to study. In the Engineering faculty at the Oslo college there has been a steady decline in recent years in the numbers of students choosing, for example, machine engineering. This tendency is even stronger in regional colleges outside city areas, and if it continues the sector will suffer from a severe shortage of well educated people in the future.

3.1 Vocational training, apprenticeships and training

Technical education with specific relevance to production of machinery and equipment is provided both at high school (vocational training) and at technical college/university level. At high school level this is limited to basics within mechanics, electronics and materials technology, and crafts such as welding and casting. On the basis of high school level skills, a worker is ready to enter the industry either directly or via an apprenticeship in a mechanical engineering firm, learning traditional crafts. There is a tendency in Norway for fewer and fewer young people to choose vocational training. This is also the tendency in the Oslo region; few students are choosing vocational training, leaving some fields of study with very few students. As a result is the competence needs of the region are not being met by the local educational institutions.

⁶⁵ University level I (one or two years), University level II (three or four years), University level III (more than four years)

Interviewees in the Oslo region emphasise this shortage of students with vocational backgrounds as a significant problem. Since the decline of the industry in the Oslo region in the last two decades, the remaining firms are often specialised in very specific areas. One problem with this is that courses relevant to these firms are not offered in vocational schools, so the firms have to train people themselves. As one manager said: “we cannot press for young people to take three years of vocational training to specialise in our very narrow field of activity, as we would then be the only firm in the region that could offer them work”. In order to meet the need for relevant education and training there are examples of firms sending workers to Sweden to get the right type of training. Some companies have also collaborated on ‘learning schemes’ in certain narrow technological fields, and these initiatives are often co-ordinated through branch organisations, institutions which seem to play an important role for some firms.

The training of employees has become an extremely important issue in the industry, both for traditional firms and for more sophisticated firms. The challenge is to make firms aware of this and encourage them to actively participate in training in order to stay competitive. Interviews give the impression that the Institute of Technology (Teknologisk institutt - TI) is of great importance for training of craft skills in firms. One firm’s manager said that TI should be seen as representing the ‘comparative advantage’ of Oslo-based firms relative to similar industries in other regions, and that TI’s activities were very important for competence-building in the firm. However, this can be a problem for firms that engage in narrow technological areas, as TI needs sufficient customers to attend each course in order to make them economically viable. One consequence of this for firms is that courses are continually cancelled, leaving firms in the region with competence-needs that cannot be met.

Even students with relevant vocational education are often not interested in entering this specific industry. The more traditional industries are often seen as labour-intensive and noisy. Attracting young, skilled workers is a great challenge for the machinery and equipment industry in the region. The shortage of young people entering the industry leaves firms with an ageing workforce. Firms therefore engage in training of employees as a way to raise competence levels, but this strategy has clear limitations: employees close to retirement have few incentives to actively participate in new training schemes. The large proportion of older employees in many traditional firms will, in years to come, force the firms to find new ways of recruiting younger workers. The industry must make itself attractive to young people, and herein lies a challenge that can in many ways be linked to companies’ innovation strategies. The ability to recruit and keep young skilled people will depend on firms’ ability to act as ‘learning arenas’.

Compared with other countries such as Germany, Norway has a rather weak tradition of apprenticeship. This is not merely due to the fact that few young people choose vocational training; students also have problems finding apprenticeships with firms in the region. The great ‘locomotives’ of the past, companies that were large enough to organise such activities, have left the region, leaving a large number of small firms with few resources. Small firms say that having apprentices is a costly process, as a skilled worker is required to supervise the apprentice, meaning that there are two workers on the floor who are not fully engaged in production. This becomes too expensive for small, struggling firms. This is in many ways a negative attitude for firms to take, as there is growth potential in new skilled workers. Public and legal

infrastructure conditions surrounding apprenticeships, such as tax-breaks and other financial incentives, are worth reconsidering.⁶⁶ Greater awareness of the potential advantages of apprenticeship arrangements could certainly help to update and strengthen the traditional skills - and the more advanced skills - needed in the industry.

3.2 Engineers

Following a process of decentralisation of engineering studies at the technical college level, there are multiple routes to the titles of 'civil engineer' and 'college engineer' in Norway. As in the rest of the educational system, there are several paths to advanced-level study, through apprenticeship and experience, through high school engineering courses, and through high school education in natural sciences.

Coming from more than a score of institutions distributed across all regions of the country, engineers are educated to different levels. Dominant subjects include firstly traditional crafts such as mechanics and electronics (and related subjects such as hydraulics and pneumatics), the newer subject mechatronics (integration of mechanics, electronics and data engineering), and the study of materials technology and properties. Secondly, product and process development subjects; product design, integrated product development, automation systems, quality control, and so on. Thirdly, subjects related to computerised control and management are important, including 3D design, reverse engineering, and programming of computerised control and manufacturing systems.

At the Oslo college there is an engineering faculty, which forges formal links to the industry in the region through students' project work. Students enter into research collaboration with the industry lasting 3-4 months. One interviewee explicitly mentioned a need to be innovative in order to attract college engineers, and that they had "thought of" making contact with the regional college to get students involved in project work related to installation of new machinery and equipment in the firm. It seems that firms have the incentives to approach the relevant institutions, but are reluctant to do so. There is potential and opportunity in many of the so-called 'mature' industries of which students need to be made aware. Technological trends in the industry point towards a greater volume of automated machinery, and there is a need for the industry to understand how new technology and processes can be integrated into existing production process within firms. There are interesting work opportunities for educated people here, and interviews indicated that this is the kind of 'knowledge' or expertise of which many firms are in great need. However, engineers are seemingly too expensive for SMEs to employ, particularly in periods when the industry is in recession.

Among more sophisticated firms, most of the employees are engineers. Many of these companies have a constant flow of students wanting to link their written projects to the firm. These firms are seen as attractive job prospects, as many of them are at the forefront of technological development in their area.

⁶⁶ Sources within providers/importers of advanced machine tools indicate a lack of education in up-to-date technological knowledge, especially in the field of production with advanced machine tools. Other sources would however argue that this kind of training should be done by other actors, e.g private or public courses.

3.2.1 Policy options

In general there seems to be a need for all parts of the industry to have some say in the kinds of vocational training that are needed in the region, and the kinds of employee-training courses that are needed. Because of the large proportion of small firms in the region, firms' actual needs in relation to vocational skills and training are not met in an efficient way. It may be beneficial to encourage networks of small firms, in which they can discuss the problems they face with respect to competence needs and make common efforts to approach the relevant authorities and institutions with their needs and concerns. However, this will not alleviate the problem of attracting young people to traditional industries.

Some firms do see a need to improve their contacts with regional colleges for the purpose of innovation, and in order to attract newly-graduated engineers to the industry. Firms need engineers to help them identify new opportunities in the industry. For engineering students, it might be interesting to participate in the modernisation of a 'mature' industry. Efforts should be made to link traditional firms to relevant higher education institutions through networks of some kind, in which the desires and needs of both the engineering graduates and the traditional firms can be discussed.

The next section will look more closely into the innovation activity of firms in the machinery and equipment industry, and attempt to clarify the process by which innovation in this industry occurs.

4. Innovation in machinery and equipment

We begin this analysis by looking at the proportion of firms in machinery and equipment that engage in innovation.

Table 8. Proportion of innovative firms in Norway⁶⁷ in the period of 1995-1997. Machinery and equipment, and all manufacturing industry. Weighted numbers. (N=163, 1976). Source: Community Innovation Survey for Norway, 1997.

<i>Sub groups</i>	<i>Nace</i>	<i>Proportions of innovative firms. Norway-Weighted</i>
Machinery and equipment	29	54%
All manufacturing industry	15-37	40%

The table shows the percentage of firms stating that, during the period 1995-97, they had introduced technologically new or improved⁶⁸ *products* and/or *processes*. In addition, they were asked whether they had, during the same period, undertaken

⁶⁷ The main idea was to use the Norwegian innovation survey and study firms manufacturing machinery and equipment, and see how they differed from the national average. However the survey had only 15 respondents from this industry in the Oslo region. We have therefore chosen to use national numbers when studying this industry; on a national level there were 312 respondents.

⁶⁸ The terms 'new' and 'improved' refer to products and processes which are new or improved from the point of view of the enterprise, but not necessarily from the point of view of the market in which the enterprise operates.

activity to develop or introduce technologically new or improved products or processes, which had not produced any results in this period, either because the results were yet to come or because the attempts had failed. If a firm answered positively to any of these three cases, the firm was classified as innovative.

The results show that the machinery and equipment industry has a larger proportion of firms reporting innovation activity than the average for manufacturing industry. This industry performs better in the Oslo region than in the rest of the country⁶⁹.

Table 9. Proportion of innovative firms in machinery and equipment in the period 1995-1997, by size. Weighted proportions. (N=163,1979). Source: Community Innovation Survey for Norway, 1997.

Size groups	Number of firms in the sample, Norway	Percentage of innovative firms in Norway. Weighted	Number of firms in the sample, machinery and equipment	Percentage of innovative firms in machinery and equipment, Norway. Weighted
10-49	1188	33%	90	42%
50-99	317	54%	34	79%
100-249	306	65%	26	88%
250+	165	79%	13	91%
All manufacturing industry	1976	40%	163	54%

We have divided the firms into size groups using number of employees as an indicator of size. The table above clearly shows that the likelihood of innovation activity increases according to the size of firms. This can be partly explained by the fact that larger firms are likely to have many product lines running at the same time, and more people to engage in the creation of new products and processes, thus enhancing their propensity to innovate in a given time period (in this case 1995-1997). In all size categories the machinery and equipment industry has a larger proportion of innovative firms than Norwegian manufacturing industry as a whole, with the greatest discrepancy found in companies with 50-99 employees (the difference being 25 percentage points), followed by companies with 100-250 employees (difference of 23 percentage points). This might be taken to suggest that the most dynamic firms are to be found within these size groups.

The table shows that there is a positive relationship between the size of a firm and its propensity to engage in innovation activity. Firms with 10-49 employees have a relatively low likelihood of engaging in innovation. This is an important finding, as it indicates that firms in this size group have a range of barriers to innovation that are related to their small size.

4.1 Understanding the innovation process

In this section we will give an overview of the innovation inputs and expenditures of the machinery and equipment industry. Examining the types of input into the innovation process will give an idea of the likelihood of innovation occurring in a

⁶⁹ Heidi Wiig Aslesen et al. in 'Performance and co-operation in the Oslo region business sector'. 1999. The Step-group. It is important to recognise that the numbers for machinery and equipment in the Oslo region are small.

firm, and tell us something about the knowledge bases required for innovation in this particular industry.

Table 10. Distribution of innovation expenditure on different activities. Manufacturing of machinery and equipment in Norway. Innovative firms. Weighted shares. 1997. (N=86, 777). Source: Community Innovation Survey for Norway, 1997.*

Weighted shares	Research and experimental development within the firm	Acquisition of machinery and equipment	Acquisition of R&D services
Machinery and equipment in Norway	50%	24%	9%
Manufacturing industry in Norway	30%	41%	14%

* The three activities on which firms spent the most when innovating.

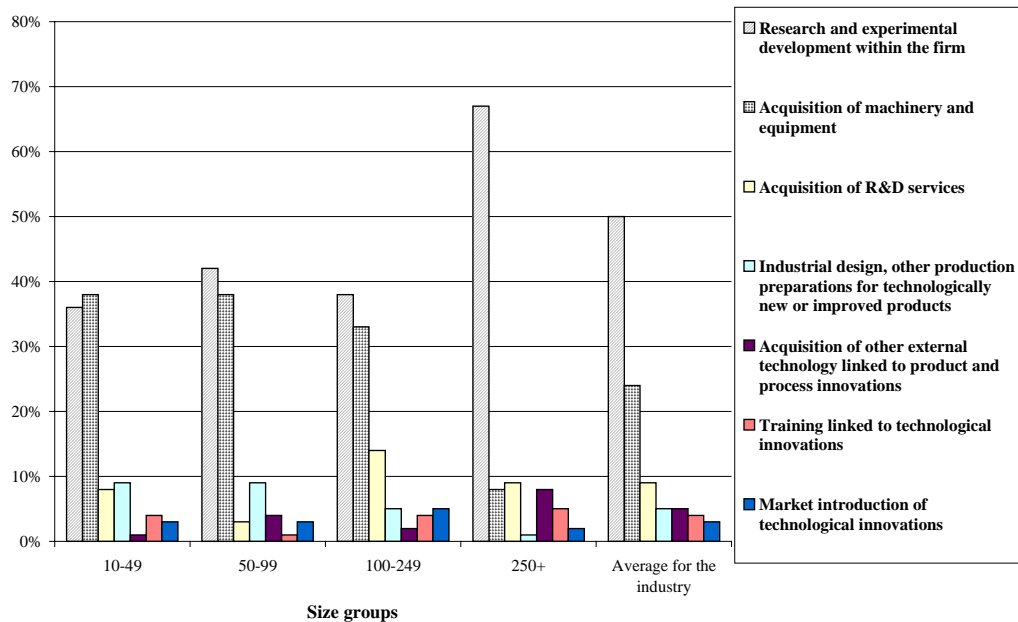
The table above lists the three innovation-related activities on which innovative firms spent the largest amount of money while innovating. The machinery and equipment industry uses half of its innovation expenditure (50%) on research and experimental development carried out within the firm. So this industry is engaged heavily in internal research and development (R&D) compared manufacturing as a whole, for which the corresponding share is 30%. Besides internal R&D, the industry also buys R&D services outside the firm: this accounts for 9% of total innovation costs. Innovators in the machinery and equipment industry spend less money on acquisition of external R&D than the average innovative manufacturing firm (9% vs. 14%). The reason for this might be linked to the industry's sub-contracting role, and its close links to customers; the need for research activity may be initiated by specifications from customers, for which solutions can only be found internally. For many firms producing machinery and equipment, every product or process is unique, having been specially developed for a single client. This will naturally have implications for firms' need for active involvement in R&D.

The importance of R&D in the innovation process indicates an industry geared towards radical innovations as opposed to incremental innovations. The R&D activity among innovative firms also suggests an industry in which firms take a long-term perspective on innovation.

Although the industry produces machinery and equipment, it also is a buyer of machinery and equipment. One quarter of total innovation costs are spent on the acquisition of machinery and equipment, a share that is much lower than the average for manufacturing industry (24% vs 41%).

In order to get a better picture of the differences in innovation strategy between firms of different size, we have divided the data on innovation expenditure into size groups.

Figure 1. Distribution of innovation costs on different innovation activities. Manufacturing of machinery and equipment in Norway. Innovative firms. By size. Weighted shares. 1997. (N=86). Source: Community Innovation Survey for Norway, 1997.



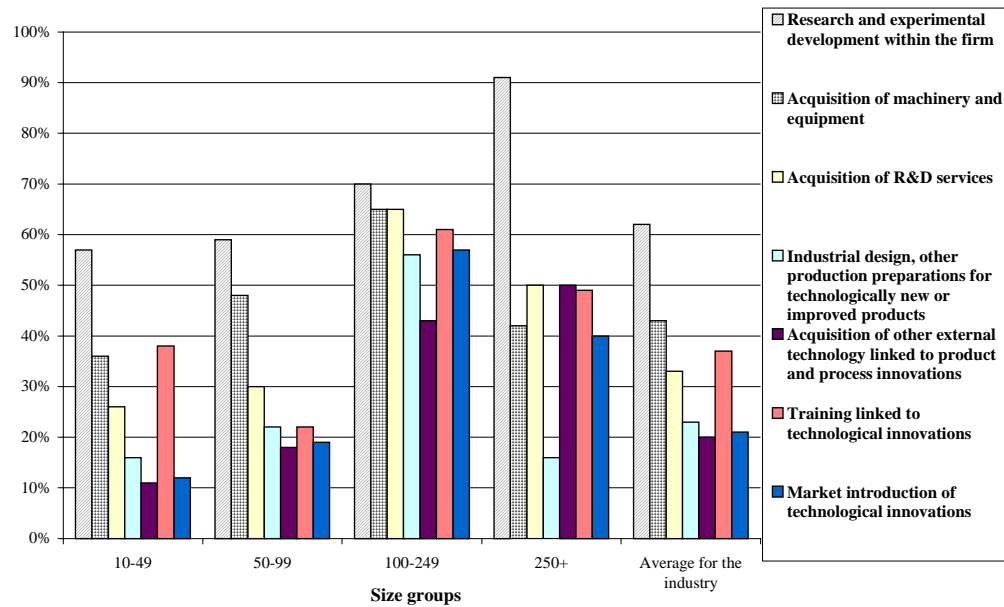
The figure above⁷⁰ shows the distribution of innovation expenditure by firm-size. In firms with less than 250 employees, ‘research and experimental development within the firms’ and ‘acquisition of machinery and equipment’ are the largest components of innovation costs. In larger firms (250+ employees) almost 70% of innovation costs are used on internal R&D. Acquisition of machinery and equipment is much less important for this size-group, with less than 10% of innovation costs used in this area. Somewhat surprisingly, we find that even the smallest firms (10-49 employees) engage in internal R&D, with as much as 36% of total innovation costs used on this activity.

R&D activity is an important innovation input for this industry, and even micro-firms (10-49 employees) are heavily involved in R&D. However, it is important to bear in mind that the ‘typical’ micro-firm does not engage in innovation at all; as noted above, only 42% of firms with 10-49 employees had engaged in innovation in the period 1995-7, leaving 58% classified as non-innovative. Through interviews with non-innovative firms it was apparent that several of them made some effort to keep informed of R&D activities going on elsewhere in which they might participate, either as a supplier of materials or as a collaborative partner, for instance in developing a prototype. However, this proactive attitude is not typical for traditional small firms, as significant obstacles exist within firms themselves, often linked to an ageing workforce critical of anything ‘new’, and to a general scepticism towards the scientific community.

⁷⁰ See appendix for a table giving exact proportions of different innovation costs.

In addition to relating innovation to firms' spending on different activities, we have mapped the percentages of firms that actually engaged in different activities, without taking into account the expenditure on that activity. Below is a figure showing the distribution of the occurrence of innovation activities by firm-size.

Figure 2. Proportion of firms taking part in different innovation activities. Manufacturing of machinery and equipment in Norway. Innovative firms. By size. Weighted shares. 1997. (N=86). Source: Community Innovation Survey for Norway, 1997.



Internal R&D activity is closely linked to the size of firms. However, it is still the innovation activity in which the largest proportion of innovative firms have engaged, regardless of size. Internal training of employees linked to technological innovation is an important innovation strategy for firms with 10-49 employees. Nearly 40% of the firms in this size group have engaged in this activity. Training is also important for larger firms; more than 60% of firms with 100-249 employees have engaged in training, and in firms with over 250 employees the proportion is close to 50%. The level of technology varies greatly from firm to firm, and this has implications for the kinds of knowledge that firms need, and the different parts of the knowledge system they use to acquire technological information. The adoption of new technology is linked to firms' technological knowledge bases; staff skills and competence-building within the firm are crucial factors in this respect. Innovation in machine tool technology is triggering demand for new knowledge from the workers, especially in relation to production process issues – the area in which most innovation has occurred in this industry. Skills and competence-building both in relation to the management of machinery and in relation to information technology are important factors for innovation in firms.

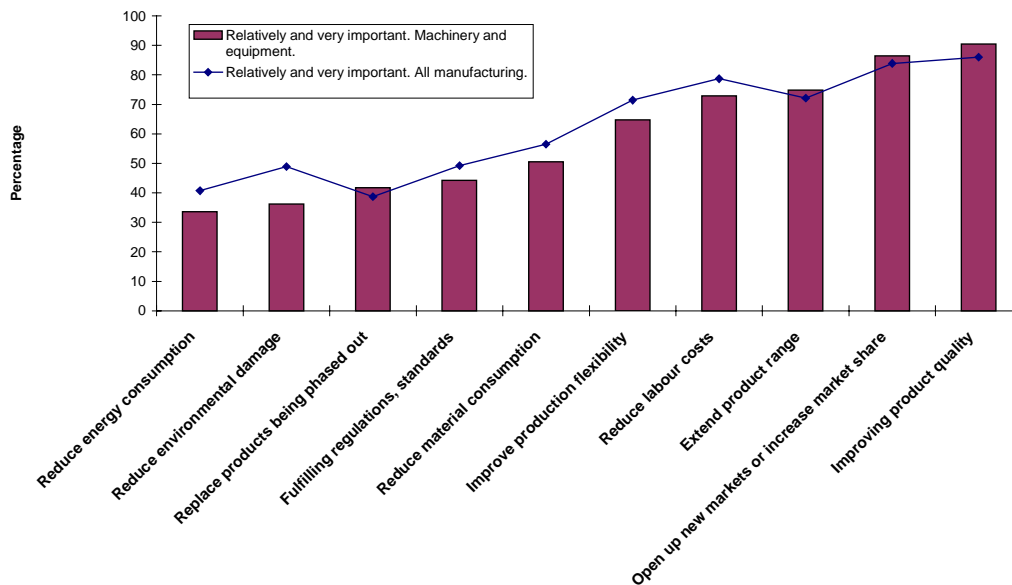
Another important difference in innovation activity between firms of different size is that firms with less than 100 employees are much less involved in the introduction of

technological innovations to the market. One reason for this could be that many of these firms do not produce products or processes that go directly to end users. Many of these smaller firms act as suppliers to other firms. Another reason could be that this activity is neglected to some degree by small firms; small firms are often preoccupied with day-to-day management, putting too little effort into the market side of the production chain.

4.2 Targets of innovation

The next step in understanding the innovation process within firms in the industry will be to identify the objectives that firms aim to achieve through their innovation activities. Firms were presented with a list of 10 reasons for engaging in innovation activity, and asked to rate the objectives according to importance. We have chosen to present the results in the form of the proportions of firms citing factors as being either ‘relatively important’ or ‘very important’ reasons for engaging in innovation.

Figure 3. Proportions of firms citing objectives as ‘relatively important’ or ‘very important’ reasons for engaging in innovation. Manufacturing of machinery and equipment and all manufacturing industry in Norway. Innovative firms. Weighted shares. (N= 101,913). Source: Community Innovation Survey for Norway, 1997.



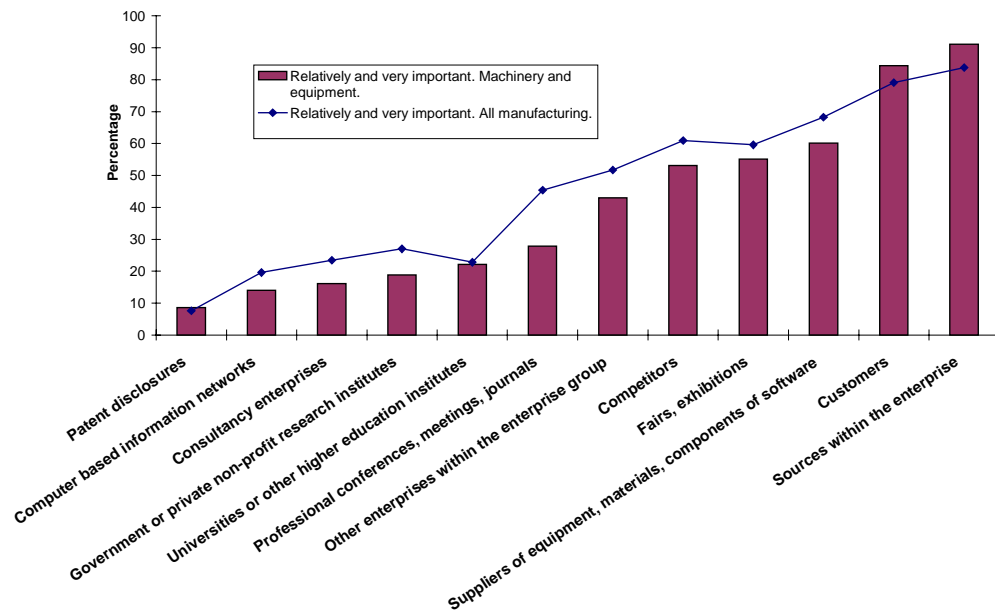
The aims of innovation are determined by the problems that industries face, the resources that are available, and the limitations of the individual enterprise. In terms of declared reasons for developing and introducing innovations, there are few discrepancies between the machinery and equipment industry and manufacturing industry as a whole. Factors relating to the products that the firm produces are clearly important, the most important being improvement of product quality, followed by

extension of the company's product range. Opening up new markets and increasing market share are also seen as important reasons for engaging in innovation.

4.3 Sources of information used by firms in pursuit of innovation

A firm's approach to information is dependent on the existing knowledge base within the firm, and on the sources of technology and information that are available in the surrounding region and the country as a whole. In this section we will map the sources of information that are used by firms in the machinery and equipment industry.

Figure 4. Proportions of firms that cited the following sources as 'relatively important' or 'very important' information sources for innovation. Manufacturing of machinery and equipment, and all manufacturing industry in Norway. Innovative firms. Weighted shares. (N= 101,913). Source: Community Innovation Survey for Norway, 1997.



There are two sources of information that stand out as the most important for innovation among firms in machinery and equipment. Firstly, 'sources within the enterprise', suggesting that information diffusion within the company itself is of the utmost importance for innovation. Secondly, customers are valued highly as an information source by a large proportion of the firms, suggesting that technological opportunities are created by 'demand pull'.

There is no doubt that customers exert great influence on producers of machinery and equipment, mainly due to the sector's sub-contracting function which implies the production of components for further industrial production. (43% of output in the sector is sold within the sector itself). Sub-contracting necessarily entails close relations with customers. Often there are detailed product measurements and specifications, to which the sub-contractor must adapt the production process. Firms

producing relatively standardised units on a larger scale have the biggest development potential in terms of the process aspects of production. Larger firms who actively use a range of technologies often produce more complex machinery, and although the products need to be manufactured to certain specifications, these kind of sub-contractors increasingly take full responsibility for technological knowledge and solutions concerning material and construction engineering. Development potential exists in all aspects of production. The existence of formal agreements between suppliers and customers is relatively common, depending on the product market. The varying complexity of the product groups in the machinery and equipment industry, and the broad range of product markets, makes it difficult to give a general description of the ways in which the sector relates to its customers.

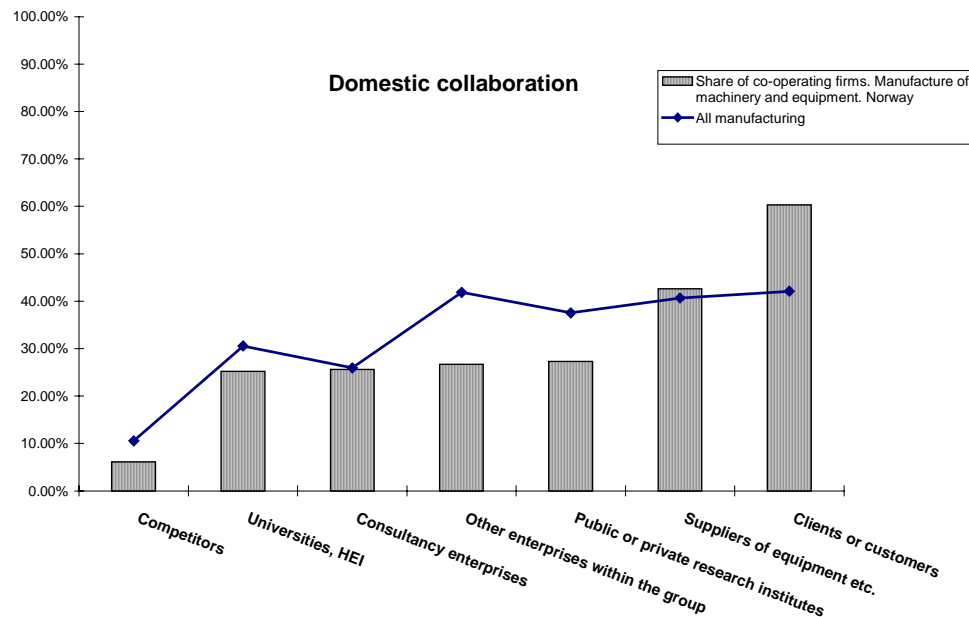
A low percentage of innovative firms value the scientific community as an important information source for innovation. This is somewhat surprising in light of the apparent importance of R&D in firms' innovation strategies. As the knowledge mapping above showed, the R&D environment - SINTEF and NTNU - is concentrated in the central parts of Norway. These institutions provide sophisticated scientific knowledge in machining technologies, suggesting some entry barriers for firms with conventional technology (which are mostly small firms). The scientific community is therefore a resource used mostly by larger firms, widening the technological gap between small and large firms. The fact that the most relevant scientific institutions are located in Trondheim is another obstacle for small firms.

Our data confirms these impressions. There is a clear difference between size-groups in the use of the scientific community: 17-18% of the firms with 10-49 employees report that information from these sources is valuable, while the figure for firms with over 250 employees is 41%.

Another source of information for innovation that firms have mentioned is branch organisations. Many firms have explicitly mentioned these as being important in the firm's pursuit of information and new ideas, and although much of their information does not focus particularly on innovation, many branch organisations are proactive in keeping firms updated on fairs and exhibitions, calls for tender and other information that could be of value for companies.

Collaboration is a formal mode of potential technology transfer, contributing complementary knowledge to the innovation process. We listed 10 different innovation partners, and asked firms to indicate whether they had collaborated with any of them on innovation. This gives an indication of the participants in the industry's innovation system, although it is difficult to judge the extent of their participation or the success of the collaboration. We will first present the domestic collaborative partners, before examining the major foreign collaboration partners as indicated by the firms.

Figure 5. Proportion of firms with different domestic innovation collaboration partners in Norway. Manufacturing of machinery and equipment. Innovative firms. (N=53, *). Source: Community Innovation Survey for Norway, 1997.



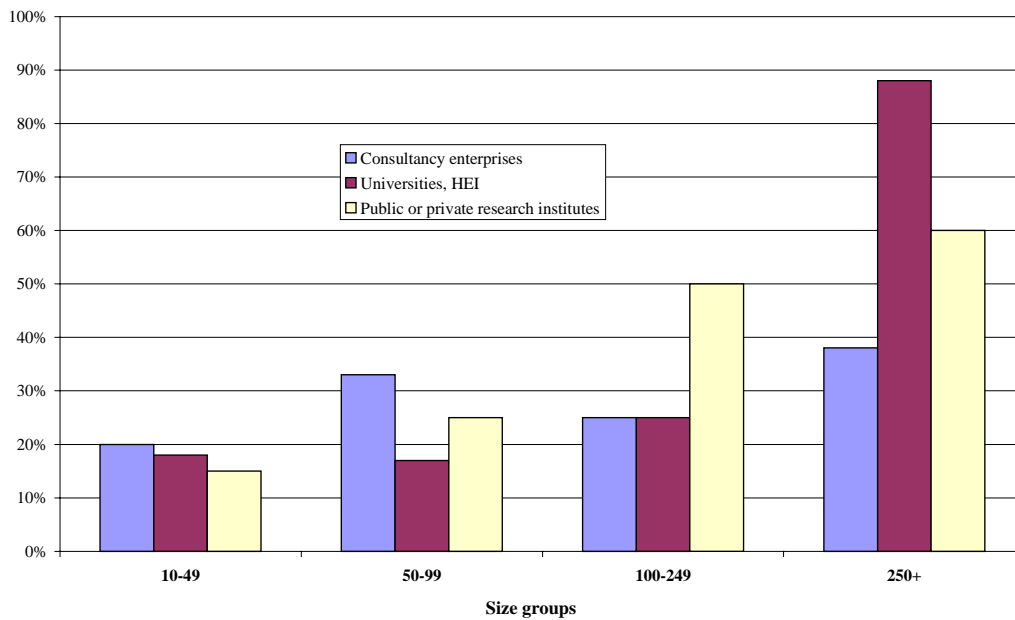
The pattern of innovation collaboration in the machinery and equipment industry is different to the general pattern for manufacturing firms in several respects. Firstly, the industry has a much larger proportion of firms collaborating with clients or customers, a symptom of its role as a sub-contractor and of technological development that is predominantly stimulated by demand-pull. Secondly, it has a relatively low proportion of firms that are part of a 'parent' enterprise group, and that collaborate with other companies in that group. Thirdly, the industry has a smaller proportion of firms collaborating with public or private research institutes. This indicates that the research and development carried out in the industry is internalised, and closely linked to specifications and prototypes given by customers. This impression is supported interviews in the industry. Firms usually develop innovations in collaboration with customers, and R&D activity is very much bound up in 'commercial interest'. There is a natural need to use resources found in the scientific community, but as noted above, the relevant research institutions are located outside the region, and the research activities in which the institutions engage are often too advanced for the purposes of smaller firms. Some interviewees mentioned that the only way to get public funding in order to carry out R&D within their firm was by linking their research activity to research institutes, implying that a major reason for collaborating with the scientific community is to receive public money. In Norway there is an apparent need for public R&D that is geared directly towards the business community, as opposed to R&D that comes via the scientific community.

After customers, the second most important domestic collaboration partners are suppliers of equipment. These suppliers seem to have a significant influence on local firms' technological development. Most suppliers of machine tools have training and skills-development as a part of their product portfolio. The region's suppliers (or

traders) organise training with their clients. This makes the suppliers of machine tools important knowledge providers to the machinery and equipment industry.

From the above analysis we have extracted three collaboration partners: consultancy enterprises, universities and higher education institutions (HEIs), and research institutes. The aim of this is to establish whether the use of these institutions as collaboration partners for innovation varies according to the size of firms.

Figure 6. Proportion of firms co-operating with different domestic actors. By size (number of employees). Manufacture of machinery and equipment in Norway. Weighted shares. Source: Community Innovation Survey for Norway, 1997.

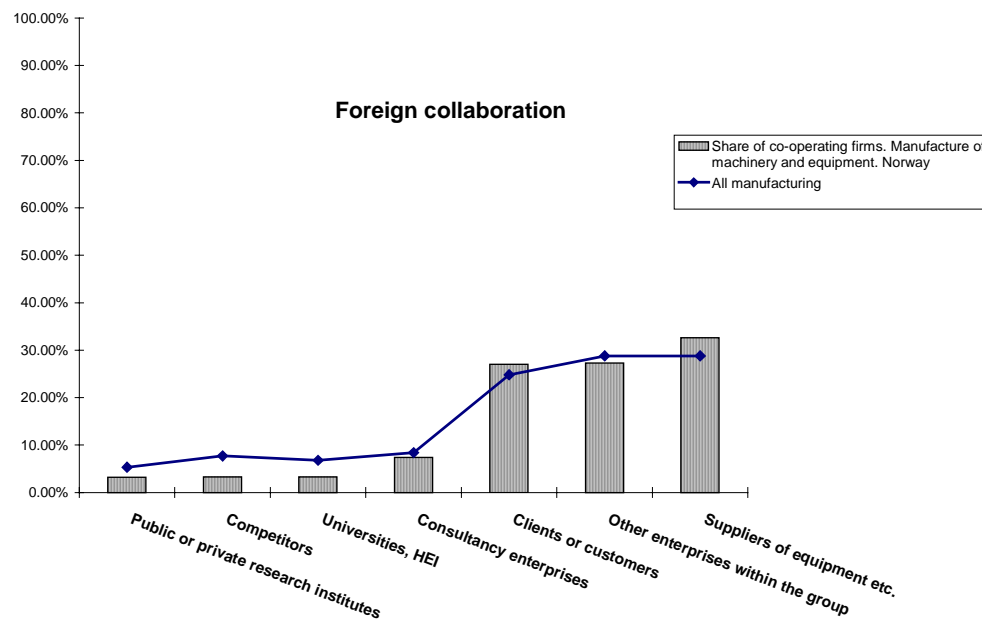


There are clear differences according to firm-size in both the extent of collaboration and the partners with whom firms collaborate. The larger the firm, the higher the proportion that have collaborated with any of the three institutional groups. For the smallest firms (10-49 employees) there are few differences between the different partners in terms of the proportions of firms that have collaborated with them. These proportions are all low (15-20%). There are many reasons for the absence of information flows and collaboration between these institutions and the smaller machinery and equipment firms. In interviews, firms emphasise that they have too little time and money to participate in projects with uncertain outcomes. Some small firms say that they are so busy coping with day-to-day problems that developing 'new ideas' is never on the agenda, although they would certainly be open to suggestions! The low use of consultancy firms is due to the fact that many consultancies are geared towards larger firms, and have few 'schemes' that are aimed at small firms. All of this implies that there are few external knowledge suppliers that are relevant to the smallest firms; the scientific community engages in activities that are too sophisticated, time consuming and expensive, and consultancy firms do not see small firms in the industry as a sufficiently lucrative market.

Consultancy firms do seem to be important for firms with 50-99 employees; almost one third of firms of this size have engaged in innovation collaboration with a consultancy.

Research institutes become more important the larger the firm; half of the firms with 100-249 employees have had innovation collaboration with an R&D institute, and for firms with over 250 employees the proportion is 60%. Universities or HEIs only become important for the firms with over 250 employees, the ‘locomotives’ of Norwegian industry. The largest firms have a far greater capacity to take advantage of the higher education institutions than the smaller firms have. Firstly they can afford to have students engaged in project work, in some cases contributing to R&D activities within the firm. However, students often have short term contracts with firms lasting only 3-4 months, and this time-span is often regarded by firms as being too short. Secondly, the largest firms are seen as attractive job-prospects by graduates, and this enables them to recruit newly-graduated engineers. In many ways the knowledge flow between the scientific community and the larger firms appears to operate well. Larger firms engage in sophisticated R&D with relative frequency, making these institutions relevant knowledge providers. These firms have both the resources and the human capital to relate to this part of the scientific community. This conclusion corresponds to our previous assumption, that the R&D activities carried out in the most relevant R&D institutions are used by those firms that are financially strong and sophisticated, and that engage in a range of different activities. Relevant R&D is also carried out in different institutes at the University of Oslo, although none of the interviewees in the machinery and equipment industry had any knowledge of their activities. There have also been lectures held at UiO that were opened up for industry to participate in, with successful results.

Figure 7. Proportion of firms with different foreign innovation collaboration partners in Norway. Manufacturing of machinery and equipment. (N=53, 777). Source: Community Innovation Survey for Norway, 1997.



Firms also engage in collaboration with foreign institutions, albeit in much smaller numbers. The main reason for finding foreign innovation partners seems to be one of necessity, in that either suppliers of vital equipment are located abroad, or other companies within the enterprise group are foreign-based. Alternatively, firms' clients and customers may be located abroad. The pattern of innovation collaboration with foreign partners by firms in the machinery and equipment sector does not differ much from the pattern for Norwegian manufacturing industry in general. Very few firms collaborate on projects with the scientific community abroad, and this may be due to a lack of personal experience or lack of trust.

5. Summary

In order for small firms in the Oslo region to catch up in terms of their technological development, there is a strong need for both financial and technological competence. It is only through attaining a certain degree of technological sophistication and efficiency that this industry can be internationally competitive.

If small firms are to close the technological gap in the future, they must be able to attract young educated people, particularly students with a background in engineering. By adopting new systems of industrial production, the industry might come to be seen as an attractive prospect. Young people have little knowledge about the industry; few have relatives employed in the industry. There appears to be a lack of awareness among young people of what this industry actually is like.

There is no lack of relevant machinery in the industry; what traditional firms need is help with putting the whole system of production together. There seems to be a shortage of both college engineers and civil engineers in the industry, and the firms need such people to help them find new solutions and to help with implementing new production lines. Traditionally, few engineers are found among the small traditional firms in the region. These firms find engineers too expensive to employ, despite their need for the knowledge they provide. There is a need to establish links between traditional firms and engineering colleges in the region, as this would help the industry in two ways. Firstly, it would help to keep students informed about the industries that exist in the region. Secondly, it would help to connect students to the firms through students' project work.

Attracting young people from vocational schools in the region is also problematic for firms. Often there are few students enrolled in the courses that are most relevant to the industry, and graduates seldom choose to work in this particular industry. There seems to be a mismatch between the needs of many small firms in the industry for certain types of education and training on the one hand, and the actual 'supply' of education and training coming from the educational institutions on the other. Networks through which these problems could be put on the agenda would be helpful in supplying the industry with workers having relevant educational backgrounds, and providing firms with relevant training schemes.

The difficulties of attracting young people with vocational and engineering backgrounds have made the training of employees an important task for firms. When firms acquire new machinery and equipment, training is often provided through the supplier selling the machinery. Other staff-training needs are covered to some degree by the Technological Institute (TI) in Oslo. However, training gaps appear in this

system, due to the institute's requirement for certain numbers of participants for each course they run. This leaves firms with competence needs not covered in the region, and the public authorities need to offer support in this area. Educational institutions are another provider of training to employees in the industry. The experience here, however, is that even if they provide the form of training that the firms themselves have specified, few firms actually take part in the training courses. Firms require training courses that are inexpensive, both financially and in terms of time. Public educational institutions also need to be more flexible in the courses they offer, in order to cater to the actual needs of the industry.

In terms of R&D activity related to the machinery and equipment industry in the region, few institutions are perceived by firms to be relevant to their needs. The most commonly used scientific institutions are located outside the region, and their projects are often too sophisticated for small firms to participate in. The colleges in the Oslo region have virtually no ongoing research projects that are relevant to the industry.

In studying firms with more than 10 employees, we found that the machinery and equipment industry had a much higher proportion of innovative firms than the national average for manufacturing industry (54% vs. 40%). The proportion of innovative firms was particularly high in the group of companies with 50-249 employees.

In many ways it seems as though the networks of relationships between the most sophisticated firms and the scientific community operate well. The attitude of these firms is: "if we need innovation help, we go out and get it". These firms also employ a high proportion of civil engineers. The best environment in Norway for finding scientific employees or scientific knowledge is in Trondheim, and regional or national borders are irrelevant to these large companies. One interviewee listed the company's reasons for being located in Oslo as: proximity to suppliers, proximity to their main market Østlandet, and proximity to R&D activity in the Gøteborg region!

Innovation in this industry appears to be very much demand-led. Market demand creates a need for R&D within the firm in order to meet customers' requirements. Many firms are closely linked to their customers, and often they see themselves as belonging more to their customers' industry than to the machinery and equipment industry.

The industry has a need for R&D that is not market-driven. Firms find it very difficult to get funding for R&D projects of this kind unless they are linked to public R&D institutions. In interviews, technologically advanced firms express a desire for better understanding from the authorities of their real R&D needs. The problem in Norway is that there are very few large industrial players in the machinery and equipment industry that have the power to press R&D plans through to fruition.

Appendix 1: List of interviewees

The tables below give an overview of the people interviewed for this study of the machinery and equipment industry, and their institutions and companies.

Table 11. Relevant institutions interviewed.

Interviewed persons	Institutions	Locations	Date
Knut Solem; Bransjeansvarlig	Teknologibedriftenes landsforbund (TBL, the Federation of Norwegian Manufacturing Industries)	Oscarsgate 20	29.09.99
Kåre Vidar Haug, Organisasjonssektretær	Jern og Metall-Oslo (Fellesforbundet)	Folkets Hus, Youngstgate 11, 0181 Oslo	06.10.99
National secretary	Fellesforbundet	Lilletorget 1	27.10.99
Student counsellor	Høyskolen i Oslo (Oslo College)	Pilestredet	4.11.99

Table 12. Interviewed firms.

Companies	Locations	Date
Sundt Brødrene maskin og service AS	Lakkegate 55 Oslo	14.10.99
Multicraft AS	Konows gate 5, Oslo	28.10.99
Kristiania Spigerverk AS	Nydalsveien 16, Oslo	27.10.99
Landteknikk A/L	Persveien 28, Oslo	25.10.99
Trioving avd. Grorud	Østre Akervei, Oslo	22.10.99
Koltech	Nygårdsveien 55, Ski	15.11.99

Appendix 2 : Tables

Table 13. Distribution of innovation costs on different innovation activities. Manufacturing of machinery and equipment in Norway. Innovative firms. By size. Weighted shares. 1997. (N=53). Source: Community Innovation Survey for Norway, 1997.

Size groups	Research and experimental development within the firm	Acquisition of machinery and equipment	Acquisition of R&D services	Industrial design, other production preparations for technologically new or improved products	Acquisition of other external technology linked to product and process innovations	Training linked to technological innovations	Market introduction of technological innovations
10-49 N=17	36% (57%)	38% (36%)	8% (26%)	9% (16%)	1% (11%)	4% (38%)	3% (12%)
50-99 N=12	42% (59%)	38% (48%)	3% (30%)	9% (22%)	4% (18%)	1% (22%)	3% (19%)
100-249 N=16	38% (70%)	33% (65%)	14% (65%)	5% (56%)	2% (43%)	4% (61%)	5% (57%)
250+ N=8	67% (91%)	8% (42%)	9% (50%)	1% (16%)	8% (50%)	5% (49%)	2% (40%)
All N=53	50% (62%)	24% (43%)	9% (33%)	5% (23%)	5% (20%)	4% (37%)	3% (21%)

Table 14. Percentage of firms taking part in different innovation activities. Manufacturing of machinery and equipment in Norway. Weighted shares. (N=86, 777). Source: Community Innovation Survey for Norway, 1997.*

Weighted shares	Research and experimental development within the firm	Acquisition of machinery and equipment	Training linked to technological innovations
Machinery and equipment in Norway	62%	43%	37%
Manufacturing industry in Norway	43%	59%	39%

* The three activities in which the largest proportion of firms engaged when innovating.

Part V: Off-shore engineering in the Oslo region

By Arne Isaksen and Thor Egil Braadland

Main findings

This report examines innovation performance in off-shore engineering in Oslo and Akershus. This area has been the centre of petroleum related engineering in Norway, holding more than half of all jobs in the sector until the mid 1990s. However, the last years have seen a sharp decrease in the relative importance of the Oslo area as a centre of off-shore engineering as measured by number of jobs, and the area's share of Norwegian off-shore engineering jobs dropped to 37% in 1998.

The report describes the regional innovation system in off-shore engineering in the Oslo area. The area has a few large companies performing EPC and EPCI contracts (Engineering, Procurement, Construction and Installation), and these companies are 'surrounded' by a large number of small, specialised engineering firms and consultants. The Oslo area also has head offices of some oil companies, and has a large number of experienced engineers. The weakest part of the regional innovation system seems to be relatively little innovation co-operation between engineering companies and R&D organisations in the area.

Off-shore engineering is a crucial part of the Norwegian innovation system in the petroleum industry, and the report describes the working of this national system. Off-shore engineering has a critical role in developing new technical solutions for oil and gas extraction in co-operation with oil companies and R&D-institutes. Off-shore engineering companies in the Oslo area also supply yards and equipment producers in other parts of Norway with tasks on fabrication and installation, i.e. the competitiveness and creativity of the off-shore engineering sector in the Oslo area is important for the activity in firms in other parts of Norway.

The report highlights and discusses two main current challenges facing the off-shore engineering cluster in the Oslo area. The first is a decreasing development activity on the Norwegian continental shelf, resulting in a decreasing demand for new petroleum installations – or at least the demand is directed towards more effective and cheaper product requiring less engineering and construction work. Thus, the hitherto largest market for the off-shore engineering firms will be significantly smaller and changed the next years. The second challenge is related more directly to the off-shore engineering cluster in the Oslo area. With decreasing activity, probably a harder fight between regions to become the centre of Norwegian petroleum industry will take place. As said, the Oslo area has been losing in importance measured by its share of employees for several years, and offensive initiatives from regional authorities may be required. The current lay-off of oil engineers in the Oslo area may also bring about some revitalisation of the regional industry. Thus, there are opportunities for

new start-ups by laid-off engineers and SMEs may have a better chance of hiring experienced engineers, opportunities which may be stimulated by public policy instruments.

1. Off-shore engineering as a producer of intermediate knowledge inputs

Off-shore engineering has partly another role in wider innovation systems than the sectors examined in the other industry studies in the Oslo RITTS project. As in the other RITTS industry studies, this study focuses on innovation performance, important sources of innovation, strengths and weaknesses of the regional innovation system etc. However, in this case it is also important to examine the role of off-shore engineering as a source of innovation in the Norwegian petroleum sector as a whole. Off-shore engineering belongs to the special group of Knowledge Intensive Business Services (KIBS) that is supposed to make a special contribution to innovation in other industries, in this case in the petroleum sector with its related manufacturing and service industries (Hauknes 1998).

The petroleum sector demands by its very nature a substantial degree of innovation activity. Each and every petroleum field needs specific technical solutions, and thus each installation is tailor-made, although mainly based on familiar technology and experiences from the exploitation of other fields. However, breakthroughs occur in specific R&D projects managed by off-shore engineering companies in co-operation with their clients, i.e. the oil companies, and R&D-institutes. Thus, off-shore engineering has a critical role in developing new technical solutions for oil and gas extraction, and off-shore engineering companies supply Norwegian yards and equipment producers with tasks on fabrication and installation.

Generally, KIBS is seen as bridging institutions in innovation systems as producers of intermediate inputs, i.e. bridging the knowledge infrastructure of universities, R&D-institutes etc. and firms (op. cit.). In that sense, off-shore engineering *may* be both on the supply and demand side in the innovation system surrounding the petroleum activity on the Norwegian continental shelf. The sector has knowledge and experience that feed into the process of improving and increasing the efficiency of equipment used in oil and gas extraction. Their clients are oil companies, and the competitiveness of these companies in gaining concession to develop oil fields to a large extent depends on technical solutions developed in co-operation with engineering companies. However, off-shore engineering also needs input from the knowledge infrastructure, as well as from customers and suppliers in their own innovation activity.

The Norwegian off-shore engineering sector covered approximately 10.000 jobs in 1998, a growth from 4.000 jobs in 1982. This increase may also reflect a general characteristic of structural change in the economy, with Business Services as the fastest growing industrial sector over the last decades in European countries (op. cit.). This growth is partly caused by a reorganisation of the division of labour between manufacturing and service sectors in national economies, with a pronounced tendency of vertical disintegration in many industries. Several large firms have outsourced activities such as research and development, design and engineering, and production, which explains part of the growth in Business Services.

Thus, in the petroleum production system a substantial amount of activity is externalised from oil companies. That is, oil companies purchase significant amount

of engineering work, goods and services from suppliers, while much of oil companies' activity is to direct and co-ordinate work done by other firms.

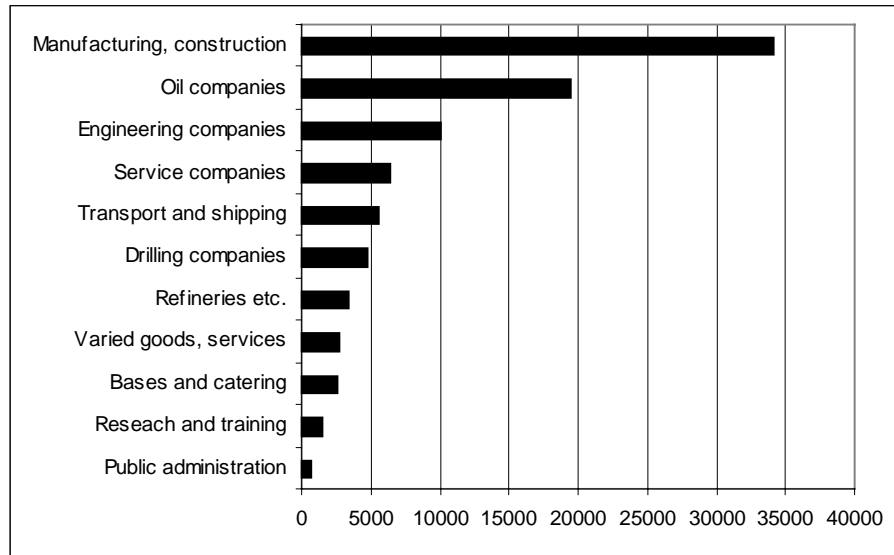
This report studies the off-shore engineering sector in Oslo and Akershus. Having the characteristics of this sector in mind, the study has a special focus on:

- a) The development (in number of jobs) in off-shore engineering in the Oslo area compared with other parts of Norway,
- b) how innovation takes place in off-shore engineering companies in the Oslo area,
- c) to which extent the sector comprises an innovative regional cluster (or a regional innovation system) in the Oslo area,
- d) the role of off-shore engineering in the national innovation system surrounding the Norwegian petroleum activity,
- e) what kind of public policy that is required in order to maintain and develop off-shore engineering as an important innovative industrial sector facing a 'maturation' of the petroleum activity on the Norwegian continental shelf.

2. The Oslo area as a centre for off-shore engineering in Norway, but of decreasing importance

The petroleum sector in Norway employed more than 90.000 persons in 1998 (Arbeidsdirektoratet 1999). This figure includes employees in all firms in Norway with activities related to the petroleum sector. The sector comprises searching, development and maintenance of oil fields, production and transportation of oil and gas ashore, which are denoted as primary activities. The sector also includes firms that deliver goods and services directly to the primary activity and specially adapted to these activities, as well as the construction and operation of refineries. The largest number of employees are found in manufacturing and construction, in oil companies and engineering companies (Figure 1).

Figure 1: The number of employees in the petroleum sector in different kind of firms. August 1998

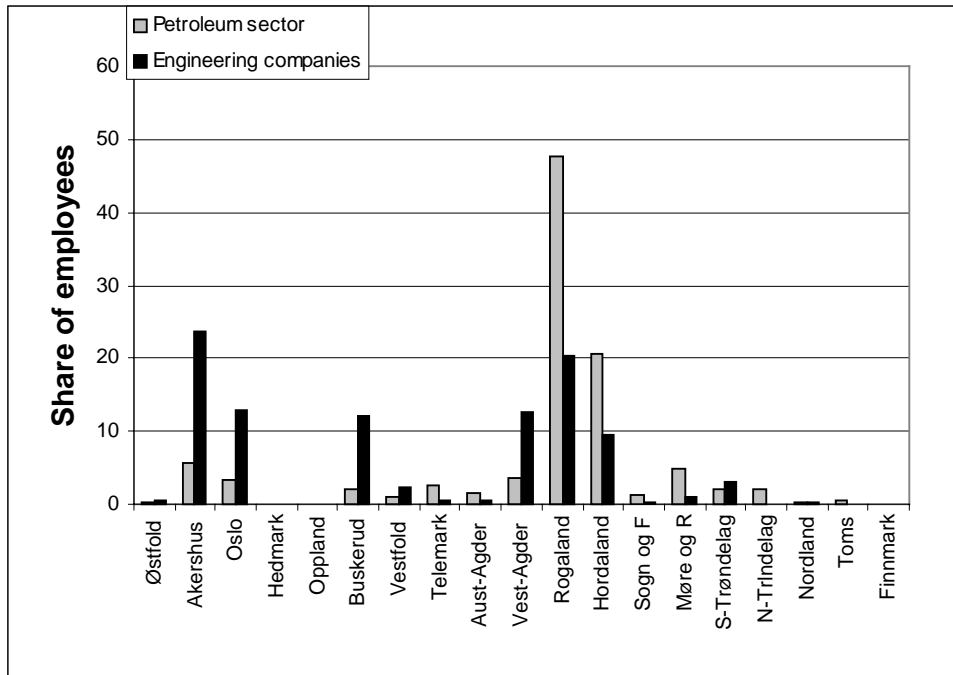


Source: Arbeidsdirektoratet 1999

The number of employees increased by nearly 12,000 persons from 1997 to 1998, caused by a very high activity in the construction of oil platforms the last year. The number of employees certainly falls in 1999, as this year experiences a large decrease in engineering and construction activities related to the Norwegian shelf.

Nearly half of all jobs in the petroleum sector in Norway are found in the county of Rogaland. Hordaland is the second most important county with nearly 19,000 employees in 1998, while Oslo and Akershus is the third most important area with more than 8,000 employees together (Figure 2). However, Oslo and Akershus have experienced a decreasing number of jobs in the petroleum sector. The two counties had 9,500 jobs in 1986, constituting 15% of all jobs in the Norwegian petroleum sector, compared to 9% of all jobs in 1998. The capital region has lost in relative importance both as a location of head offices of oil companies and in off-shore engineering.

Figure 2: Share of the employees in the petroleum sector and in off-shore engineering in different counties. August 1998



Source: Arbeidsdirektoratet 1999

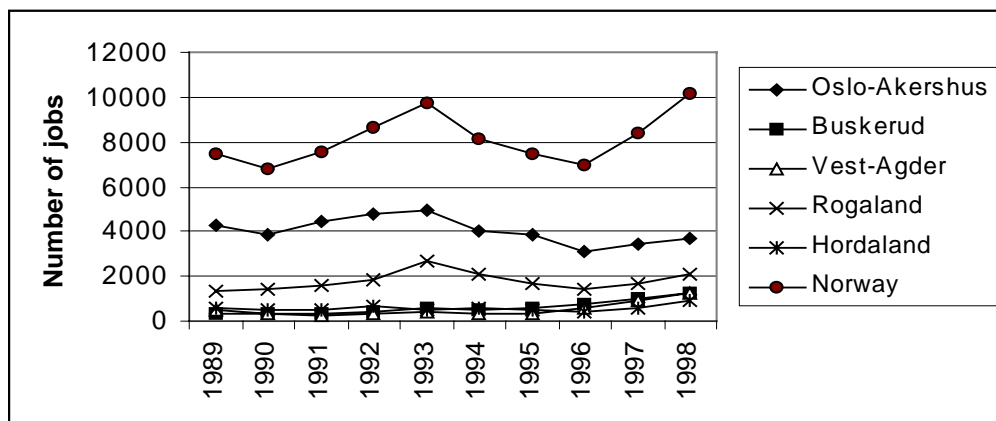
Looking only at off-shore engineering companies, Oslo and Akershus is still the most important area in Norway with more than one third of the national employment. Off-shore engineering constitutes nearly half of all jobs in the petroleum sector in Oslo and Akershus, while only 5% of the jobs in this sector in Rogaland. However, Rogaland is the second largest centre of off-shore engineering in Norway with approximately 2.000 jobs in 1998. Off-shore engineering also has a concentration in Vest-Agder and Hordaland, while also Buskerud, nearby the Oslo region, has relatively many jobs in off-shore engineering (Figure 3).

The number of jobs in off-shore engineering in Oslo is dominated by a few large firms, first and foremost Kværner Oil & Gas and Aker Maritime Oslo⁷¹. These are the engineering unit of the two large integrated suppliers of platforms and other production facilities (Kværner and Aker) that traditionally have dominated the Norwegian petroleum market concerning engineering and production. However, at present both these companies are downsizing. At the end of 1999, Kværner Oil and Gas in Oslo goes down by 250 employees to 750 in the first round, while Aker shrinks from 650 to 500 employees. Aker Maritime Oslo had as much as 1.400 employees four years ago. ABB Offshore Systems with 300 employees is another large engineering company in the Oslo area. Contrary to Kværner and Aker, this company has increased sharply in the number of employees the last years.

⁷¹ We here use the term Aker Maritime Oslo to denote the two firms Aker Engineering AS and Front End AS. The first company perform engineering, procurement and project management. The second company execute conceptual studies and other front-end activities up to start of project realisation.

The Oslo area has lost in importance in the Norwegian off-shore engineering sector over the last 10 years as measured in number of employees (Figure 3). Thus, the Oslo area has a smaller number of jobs in off-shore engineering in 1998 than 1989, while other counties with much off-shore engineering reveal a sharp increase in the number of off-shore engineering jobs in the same period. Oslo and Akershus had 57% of all jobs in off-shore engineering in Norway in 1989, the area had 52% of the jobs as late as 1995, while only 37% of Norwegian off-shore engineering jobs in 1998. The Oslo area increased its number of off-shore engineering jobs between 1995 and 1998, however, at a much slower rate than in the rest of Norway.

Figure 3: The number of jobs in off-shore engineering in Norway and selected counties



Source: Arbeidsdirektoratet

Several questions arise concerning the relatively large number of jobs in off-shore engineering in the Oslo area, and the relative decrease in the number of jobs the last years: 1) What explains the concentration in off-shore engineering in this area? 2) Does off-shore engineering constitute a regional innovation system in the Oslo area? 3) Why has the area lost in relative importance the last years? 4) What are adequate public policy instruments to increase the competitiveness of the off-shore engineering sector in the Oslo area?

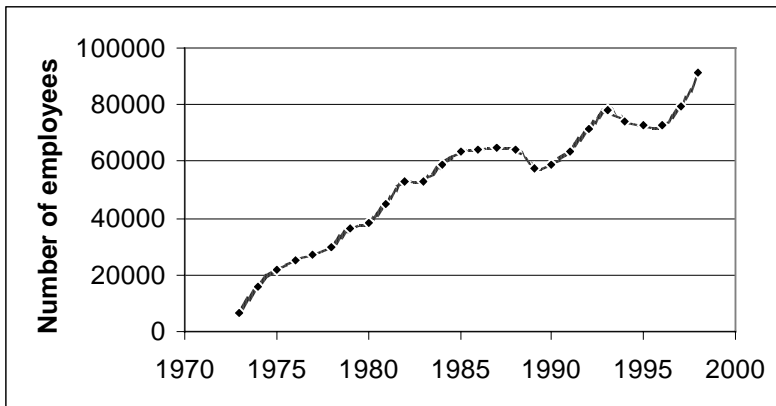
We try to answer the first question by describing the historical development of off-shore engineering in this area. Why did off-shore engineering firms start up at an early stage in the Oslo area, and why has the area still a relatively large number of jobs in this industry? However, before answering this question we will, as a background, give a short presentation of the growth of the petroleum sector in Norway. The recent technological change in this sector also gives some hints to why Oslo has lost in relative importance in off-shore engineering the last years.

3. The growth of the petroleum sector in Norway

The first petroleum discoveries on the Norwegian continental shelf were made in the late 1960s (the Cod and the Ekofisk fields). A totally new industry, as well as a national innovation system in the petroleum sector, has been built up in Norway since then, comprising about 91.000 employees in 1998 (Figure 4), and constituting the largest export sector in Norway. While foreign companies and foreign knowledge and technology were important at the beginning of the 'petroleum period', Norwegian companies and technology now dominate in this industry. Since the second half of the 1980s between 75 and 90% of the supply to field development on the Norwegian shelf has been supplied by Norwegian firms (Braadland 1998).

This nationalisation of the petroleum industry, including the creation of the off-shore engineering cluster in the Oslo area, builds on two main mechanisms. First, although knowledge in petroleum activities was very scarce in Norway in the 1960s, important competence that could be adapted to use in the petroleum sector were nevertheless found in already existing industries and knowledge infrastructure in Norway. These 'receiver competence' were found in shipping, shipyards, concrete construction, iron and steel working, large-scale bridge building, energy production, nature science, and geological research. Thus, in several industries firms restructured their activity to meet the new demand of goods and services from oil companies. In this way the petroleum activity has had an innovation inducing effect (Haraldsen 1997).

Figure 4: Number of employees in petroleum activities in Norway 1973-1998



Source: Arbeidsdirektoratet 1999

Second, Norwegian authorities played a decisive role in the restructuring of Norwegian industry in their efforts to create a new innovation system organised around the petroleum activity. Thus, backed up by public initiatives, technology and competence were transferred to Norwegian industry and R&D-institutes from outside, and new competence developed. Thus, the outcome of the negotiations between Norwegian authorities and oil companies in the mid 1960s was that the companies' share of field development to a large extent should reflect the degree of co-operation and subcontracting between oil companies and Norwegian firms

(Hanisch and Nerheim 1992). The establishment of the technology agreements between oil companies and the Norwegian state in 1979 became one important way of canalising R&D funding. Technology investments by oil companies in Norwegian firms and R&D-institutes were rewarded by governmental goodwill in the concession rounds. Between 1979 and 1990 more than 7 billion NOK were transferred to Norwegian R&D institutions and firms, and a considerable amount of interactive learning and technological development in collaboration with foreign oil companies took place. These agreements came to a halt due to the Economic Area Agreement in 1993.

During the 1970s and 80s, the large oil fields on the Norwegian shelf and the high oil price allowed for a pervasive 'concrete platform' field development; a high cost production technology termed as 'the Norwegian style' (Olsen 1994). New technological and organisational innovations have taken place due to new requirements. Large oil fields are about to run dry, the discovery rate is low, the remaining oil and gas reserves are located in gradually smaller entities, and a shift of the activity from field exploration and development to production and maintenance takes place. Internationalisation processes also influence the Norwegian petroleum industry in two main ways. First, these processes increase competition in Norway as foreign firms extend the potential number of suppliers of goods and services. Second, Norwegian companies may compete in the exploitation of oil and gas fields in other parts of the world. Thus, in 1995 the petroleum sector exported goods and services (other than oil and gas) for approximately 12 billion NOK, where the largest exports were equipment/systems, engineering, rig services and seismology (Braadland 1998).

The smaller oil fields, cost press etc. contribute strongly in the transition to a new techno-economic path characterised by a shift from the large platforms to more flexible and cost effective solutions, where Norwegian oil companies and engineering firms have been at the front (Haraldsen 1997). Examples of technological innovations are subsea production facilities, small satellite installations (subsea or surface) surrounding a central platform, tension leg platform, production ships (FSOP-ships⁷²), horizontal drilling, as well as injection systems (to get more oil out of existing fields). Although the large engineering firms in the Oslo area have been active in developing new technology they have to a certain extent been 'locked into' the old techno-economic path focusing on large and expensive solutions. Thus, Kongsberg Offshore Systems and ABB Offshore Systems are in the forefront in developing subsea installations, while Aker Maritime has no subsea activity. This 'lock in' to the old techno-economic path may partly explain the recent decrease in relative importance of off-shore engineering in the Oslo area.

Another aspect of the new techno-economic path in Norwegian petroleum activity is the fact that gradually more work and responsibility are shifted away from the oil companies to their suppliers. Thus, oil companies tend to pass on from EP (Engineering, Procurement) and EPC (Engineering, Procurement, Construction) to EPCI (Engineering, Procurement, Construction, Installation) contracts and 'turn key' contracts (op. cit.), as a kind of organisational innovations. EPCI means fewer and larger contracts, which benefits first and foremost large companies with sufficient technology, capital and project experience, either by having the ability to

⁷² Floating, Production, Storage, Offloading.

manufacture a broad range of product internally, or the ability to manage, control and co-ordinate a broad range of suppliers. Of the Norwegian engineering companies, Kværner Oil & Gas, Aker Maritime, ABB Offshore Systems and Umoe perform EPCI-contracts (as well as modification, maintenance and reuse of existing installations). These companies are involved in all phases of oil and gas development, both offshore and on land. With this kind of contracts responsibility and economic risks are transformed from the oil companies to the engineering firms.

This new way of organising field development followed from a joint project in the mid 1990s (NORSOK) between public authorities, oil companies and suppliers, with the aim of reducing the costs on the Norwegian shelf with 40%. EPCI was seen as one way to reduce costs due to a better total view of the project and less administration costs. However, most firms have lost a lot of money on their EPCI contracts the last years, among other things due to changes during the project, and a lack of overview and control of the technical and cost consequences of changes. The contract forms may be changes in the near future, and oil companies now seem do more engineering and calculation themselves prior to inviting tenders⁷³.

4. A short history of off-shore engineering in the Oslo area

The development of petroleum activity on the Norwegian shelf resulted in a growing, 'independent' off-shore engineering sector in Norway. Right from the start, a kind of technical co-operation instead of vertical integration took place in the petroleum industry; i.e. oil companies handed over a lot of engineering work to independent engineering companies instead of building large internal engineering departments.

The first engineering work connected to the petroleum activity was carried out in the Oslo area, as this was the only region with a sufficient number of qualified engineers (Isaksen 1990). Engineering divisions in some large Norwegian manufacturing and construction companies were the origin of the first independent engineering firms which served the market for technical consultancy in the North Sea. Thus, engineering firms as Kværner and Aker Engineering sprouted from the head offices and engineering departments of the then large, and Oslo based manufacturing firms.

Kværner Oil & Gas was for example established in 1966 as Kværner Engineering. From the beginning the company's task was to develop new technology connected to the manufacturing of gas tankers at Kværner's ship yards. Soon after the establishment of Kværner Engineering, the company also became the instrument to develop competence in oil and gas activity inside Kværner, triggered by the first petroleum discoveries in the North Sea. The first work was carried out for the Norwegian Ministry of Industry in 1971; an analysis of alternative uses of gas from the *Ekofisk* field. The company grew slowly throughout the 1970s, but experienced a very rapid growth at the beginning of the 1980s due to increased petroleum activity on the Norwegian shelf and a 'nationalisation' of this activity

The Oslo area was more or less the natural location site of these new engineering firms, as this area was the foremost location of head offices in Norway, which, as

⁷³ Interview with Asbjørn Jarle Ferstad, ABB Offshore Systems AS October 28 1999.

said, was the seed bed of the new engineering firms. Traditionally nearly half of the 500 largest companies in Norway have found their head offices in the municipality of Oslo. The nearby municipality of Bærum follows, after Oslo and Bergen, with the number of head offices (Rusten 1990). The new independent engineering firms were located nearby the head offices and in the area were most of the employees lived.

The early start of off-shore engineering in the Oslo area and the extensive activity in this field gradually created favourable conditions for further growth of new engineering firms in this area. Specialised competence was created at an early stage, that was a competitive advantage for new firms. The single most important locational advantage of off-shore engineering firms in the Oslo area is still found in the large number of specialised and experienced engineers in this area⁷⁴. The considerable growth in demand for technical consultancy in the petroleum sector during the 1970s and 80s also resulted in a certain vertical disintegration inside the engineering sector. A number of subcontracting firms were set up in periods of growing petroleum activity with its increasing demand for engineering work. These firms partly supplemented the larger engineering companies by offering specialised competence, and partly offering extra engineering capacity. For example, in periods of high activity qualified labour has been a bottleneck in off-shore engineering, and a large market existed for companies which hired out engineers.

Thus, a lot of smaller engineering firms have been established in the Oslo area, often as spinn-offs from the large ones in the same area. Then, the question of where (in which geographic area) to locate the firms seldom arose. The entrepreneurs locate the firms in the area where they already work and live and have their contacts, i.e. in the Oslo area. However, it has also been an advantage for these firms to locate close to the large engineering companies that carry out the major work for the oil companies. Proximity increases the opportunities for fast and frequent contact 'face-to-face', and in some cases the contacts are between former colleagues from the few, large engineering companies. Several smaller projects are assigned without bidding, and then it becomes important to meet people outside work in order to obtain information quickly. Geographical proximity also implies cheaper hourly rates for similar tasks (since travel and cost expenses, are not incurred in connection with the projects). Much of the work has to be carried out in the localities of the large engineering companies. Thus, Kværner Oil & Gas normally has around 1.000 hired consultants, which are mainly engineers specialised in specific areas⁷⁵. The number of hired consultants has been equally to the number of employees in Kværner, however, the number of consultants is now cut down due to downsizing of the company.

The spinn-off activities and establishment of smaller engineering firms have created a network of co-operating large and small engineering firms in the Oslo area, where most of the firms are located within the 'Engineering Valley' from Oslo to Asker. Thus, the concentration of off-shore engineering in this area has to be seen in a historical context. The early start of off-shore engineering in the area was caused by a concentration of head offices and engineering department in manufacturing and construction firms in this area. The early start created favourable conditions for

⁷⁴ Interviews with firm leaders in Kværner Oil & Gas, Aker Engineering and ABB Offshore Systems in October 1999.

⁷⁵ Interview with Kirsten Økern October 26. 1999.

further growth in the Oslo area due to the accumulation of specialised knowledge, and a multitude of smaller engineering firms grew up to complement the larger ones.

The recent downsizing of large engineering firms as Kværner Oil & Gas and Aker Maritime Oslo reflects a dramatic fall in development activities on the Norwegian shelf following the low oil price at the turn of this year. Even with higher oil prices few plans have been taken up again and implemented. However, off-shore engineering jobs are also moving away from Oslo, in the sense that this area has experienced a sharp decrease in its share of all off-shore engineering jobs in Norway, while especially Buskerud, Vest-Agder and Hordaland increase their share. This represents a challenge to local authorities to be discussed in the final section of the report.

5. Innovation activity in technical engineering in the Oslo area

What characterises innovation activity in the off-shore engineering industry in the Oslo area? Does the sector constitute a regional innovation system? We answer these questions by a combined analysis of results from the Community Innovation Survey in Norway (CIS II), and information from firm interviews.

When using CIS II, one has to remember that off-shore engineering is not a separate industrial sector in the statistical classification. Off-shore engineering forms an integrated part of 'larger' industrial sectors, i.e. of NACE 74.2 'Architectural and engineering activities and related technical consultancy', and NACE 74.3 'Technical testing and analysis'. Thus, when using statistical sources as CIS II, we have to analyse innovation performance in these two NACE sectors, that we denote as 'technical engineering'. However, off-shore engineering is an important subgroup in these NACE sectors in the Oslo area. The largest firm in these two sectors in the Oslo area (according to the Employer-Employees Register) is Det norske Veritas AS, which is an important collaborator for the off-shore engineering companies. The two second largest firms in technical engineering, Kværner Oil & Gas and Aker Engineering, are both engaged in off-shore engineering.

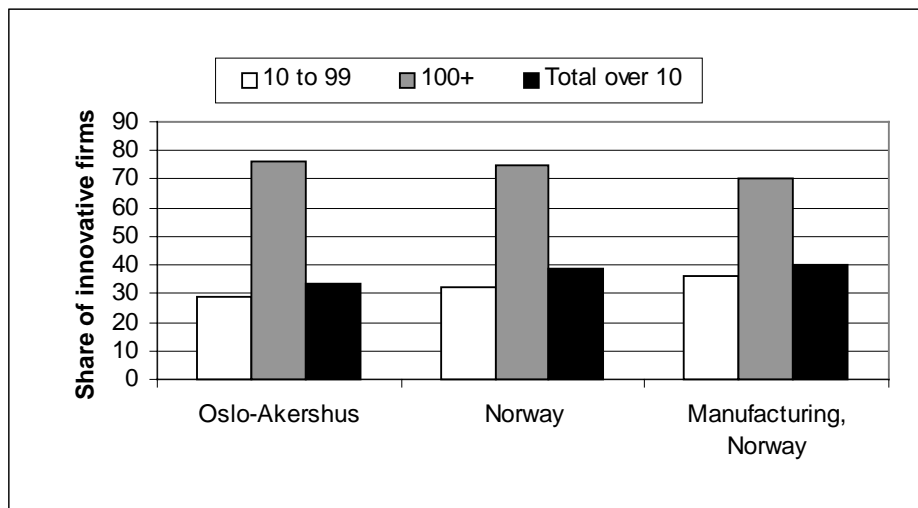
In examining data from CIS II, we first have to be aware of the basic conceptual distinction in this survey between firms which are innovative or not. Firms are classified as innovative or not according to their answers on a few questions at the start of the survey. Firms in the service sector (which technical engineering belongs to) were asked if they during the period 1995-97 introduced any new or significantly improved services or methods to produce or deliver services. In addition, they were asked if they during the same period undertook activity to develop new or improved services that had not produced any results in this period, either because the results were yet to come or because the attempt had failed. If a technical engineering firm answered yes to any of these two questions, it is classified as innovative.

It is important to notice that the term 'new' and 'improved' refers to services and methods which are new or improved to the firm, but not necessarily new to the market. CIS II studies innovation activity inside firms, and not, for example, how technical engineering firms may contribute to innovations in other firms – as we see as a very important activity for business service firms in general.

CIS II included 71 technical engineering firms in Oslo and Akershus and 187 technical engineering firms in Norway as a whole, which also points to the high concentration of this sector in the Oslo area. Oslo-Akershus had a bit lower share of innovative firms in technical engineering than the Norwegian average (Figure 5). While 33% of the firms in the Oslo area are classified as innovative, the figure for Norway as a whole is 39%. As a comparison, 40% of manufacturing firms in Norway are classified as innovative, i.e. they had introduced new or improved products or processes during the period 1995-97.

However, Figure 5 reveals that the comparatively low share of innovative firms in technical engineering in the Oslo area is brought about by relatively few innovative small firms (10-100 employees) in this area. The large firms in Oslo-Akershus are more innovative, as measured by CIS II, than the large firms nation-wide. Although the share of innovative small firms in technical engineering is not dramatically lower in the Oslo-area than nation-wide (28 and 37%, respectively), it may be important to clear up the causes to this lower innovation activity.

Figure 5: Share of innovative firms in different size classes in technical engineering in Oslo-Akershus and Norway, and compared with manufacturing industry in Norway



Source: CIS II from Statistics Norway

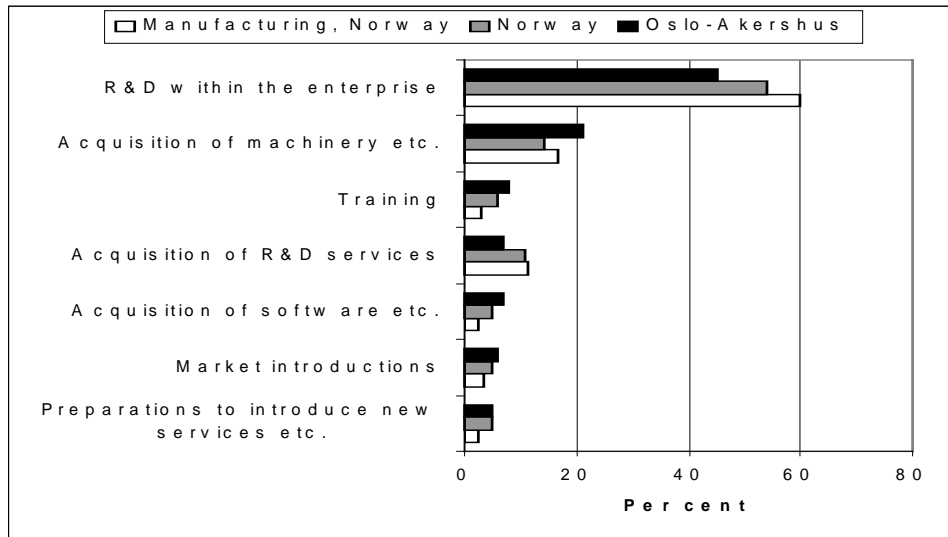
Turning to off-shore engineering, we clearly see a pattern of large innovative companies surrounded by highly competent smaller firms that often do not innovate themselves.

The large companies have to be innovative; they have to come up with new technical solutions and products that reduces the cost of petroleum extraction for the oil companies in order to gain a contract. Either the companies are innovative or they disappear from business in a few years time. Several consultants and smaller engineering firms take part in innovation projects in the large companies, both the engineering work to tailor-make installations to the specific requirements of each oil field and the development of new products to be used in subsequent projects. Thus, smaller firms participate in the innovation processes in the large companies, and they have specialist knowledge that the large companies often do not hold themselves to feed into these processes. However, the firms often do not have their own product or services, nor do they develop new or change existing product and services in house. The firms are a kind of specialist subcontractors working directly on the customers own innovation projects, but they are not innovative themselves in the way innovations are registered in CIS II. Then, this way of organising engineering work and innovation projects in off-shore engineering contributes in explaining the high share of innovative large engineering firms and the relatively low share of innovative smaller firms as revealed in CIS II. To measure innovation activity inside firms is not always the most relevant indicator in such an integrated production system as off-shore engineering in the Oslo area. What counts is the quality of new products and solutions developed by the larger companies, but they use the competence of numerous smaller engineering firms in their innovation activity.

5.1. Innovation performance in technical engineering in the Oslo area

How do technical engineering firms in the Oslo area innovate? One way to analyse innovation performance is through innovation costs. CIS II registers what kind of costs firms have in connection with their innovation activity. Figure 6 reveals that technical engineering firms in the Oslo area spend less money on R&D activities than both engineering firms elsewhere in Norway and Norwegian manufacturing firms in average. Technical engineering firms in Oslo-Akershus spend relatively less on internal research and experimental development within the enterprise, as well as less money on acquisition of R&D services from external actors compared with technical engineering firms in the rest of Norway.

Figure 6: Costs used for innovation activities in technical engineering firms in 1997

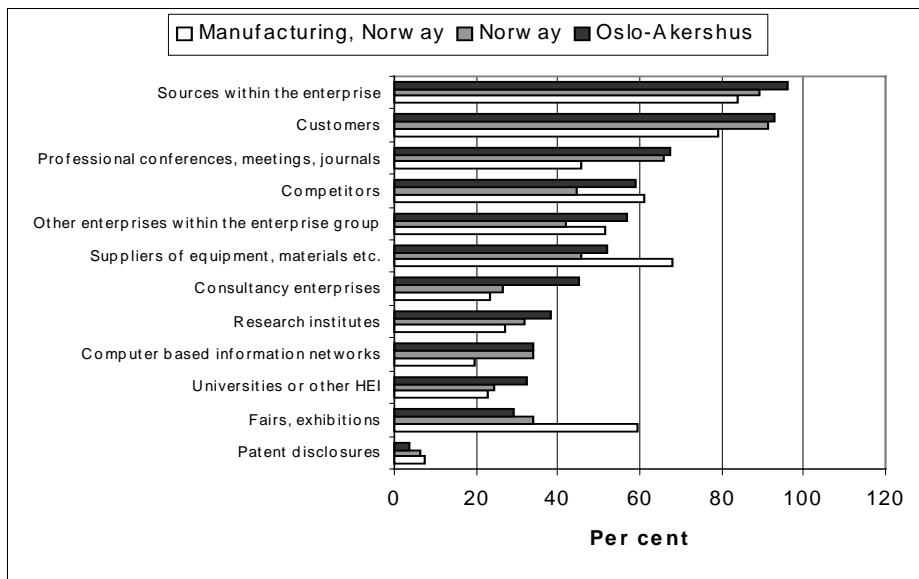


Source: CIS II; Statistics Norway

The relatively low R&D spending in Oslo firms may at first glance be surprising as long as firms in Oslo and Akershus have a shorter travelling distance to universities, other higher education institutions and research institutes than firms in most other parts of Norway. Thus, as research collaboration may be stimulated by proximity, firms in the Oslo area should have better opportunities for performing research in collaboration with external actors and acquire R&D services from nearby knowledge organisations. Thus, manufacturing firms in the Oslo area use a much larger share of their innovation costs on internal R&D than manufacturing firms in the rest of Norway, while this is quite opposite for technical engineering firms.

To further examine how technical engineering firms in Oslo and Akershus innovate, we analyse to which extent they utilise different sources of information when innovating. A general conclusion from Figure 7 is that technical engineering firms in the Oslo area employ more information sources at the same time than technical engineering firms in the rest of the country, i.e. firms in Oslo-Akershus cite more information sources as very or moderately important than this kind of firms in the rest of Norway. Competitors, other enterprises within the same enterprise group, consultancy enterprises, research institutes, and universities and other higher education institutions are in particular important information sources of technical engineering firms in the Oslo area.

Figure 7: Share of technical engineering firms who say that different sources of information for innovation are very or modestly important



Source: CIS II, Statistics Norway

These results may demonstrate the importance of information from the engineering and larger industrial and knowledge milieu in the Oslo area. This is confirmed by other results from CIS II, namely of innovation co-operation between technical engineering firms and other actors. A much larger share of technical engineering firms in Oslo-Akershus co-operates with other actors when innovating. In particular, a higher share of Oslo firms has innovation collaboration with competitors, consultancy enterprises and research institutes.

These results indicate that technical engineering firms in the Oslo area benefit from knowledge spill-over from competitors, consultants and knowledge organisations in this area. That is, firms may acquire some information and knowledge more or less as a result of their location in a wider industrial and knowledge environment. Then, technical engineering firms in the Oslo area may perhaps not need to perform or acquire the same amount of research and development as more 'isolated' firms in other parts of Norway, as the firms in the Oslo area gain much from their location. Thus, the results from CIS II indicate that a regional innovation system of technical engineering may exist in the Oslo area. This sector constitutes a regional cluster in Oslo-Akershus, and technical engineering firms in the area reveal a high degree of innovation collaboration with other firms and knowledge institutions.

6. A regional innovation system in off-shore engineering in the Oslo area?

The conclusion concerning the existence of a regional innovation system in technical engineering also applies to off-shore engineering in the Oslo area. To constitute a regional innovation system, off-shore engineering – or another branch of industry –

must fulfil three conditions. First, the industry must form a regional cluster, that consists of a geographically bounded concentration of interdependent firms (Rosenfeld 1997). Then the firms form a local production system, or the firms are interlinked in other ways, for example by the use of a common knowledge base or the same raw materials.

Off-shore engineering in the Oslo area certainly forms a regional cluster. This area is the centre of off-shore engineering in Norway as measured by number of employees. The area consists of a few large engineering firms and numerous smaller engineering firms working as subcontractors to the larger ones (cf. section 7.2). The large firms find their most important locational advantage in the large number of specialised engineers in the Oslo area⁷⁶. Specific competence in off-shore engineering has been built up over 20-30 years, which constitutes more or less a common knowledge base for local firms to tap into.

The other main location advantage is related to the wider industrial milieu of off-shore engineering in this area, normally specified as 'localisation economies'; the presence of same-sector businesses and employees. The wider off-shore engineering milieu in the Oslo area consists of the Oslo offices in the oil companies, although most head offices are located in Stavanger. Next, the large engineering firms themselves co-operate on some projects, even though they compete on other bids. Thus, Kværner Oil & Gas and Aker Maritime have a long history of co-operation on concrete projects if not on product development. Kværner and Aker now have a joint venture agreement on oil installations for the Snorre B field. The Oslo area also has a wide range of specialised firms that offer specific competence to the off-shore engineering firms. The second condition for constituting a regional innovation system is precisely formal co-operation on innovation projects between local firms.

The third condition includes innovation co-operation also with knowledge organisations, i.e. that universities, R&D-institutes etc. are involved in innovation co-operation in the off-shore engineering sector. The off-shore engineering companies collaborate to some extent with knowledge organisations, mainly NTNU, SINTEF both in Trondheim and Oslo, Chr. Michelsen Research in Bergen and foreign R&D-institutes. The co-operation concerns both solutions in concrete field developments and more generic technology development outside off field projects. Thus, the third condition is also fulfilled. However, few R&D-organisations in the Oslo area are actually involved in innovation projects in the engineering firms, and the weakest part of the regional innovation system seems to be relatively little innovation co-operation between off-shore engineering firms and the regional knowledge infrastructure (This is further discussed in section 7.3 and 8).

⁷⁶ Results from interviews in both Kværner Oil & Gas, Aker Maritime Oslo and ABB Offshore Technology.

7. The innovation system in the Norwegian petroleum industry. Defining the role of off-shore engineering in the Oslo area

The Norwegian petroleum industry constitutes a *national*, rather than a regional production and innovation system. What role does off-shore engineering in the Oslo area have in triggering innovation activity in the Norwegian petroleum industry as a whole?

National systems of innovation are seen as systems of *interconnected actors* (like firms, organisations and government agencies) that interact with each other in ways which influence the innovation performance of a national economy, and that this interaction takes place within a specific national context of shared norms, routines and established practices. Thus, the interest in national innovation systems is based on the viewpoint that the innovation capabilities of a nation's firms are a key source of their competitiveness, and that these capabilities are largely national and can be built by national policies (Nelson and Rosenberg 1993).

Innovation systems are open systems, and a specific firm may be part of several innovation systems, be they sectoral, regional and national, at the same time. Although there are also many similarities in innovation systems between countries, some striking differences are seen to exist. Thus, Gregersen and Johnson (1997), for example, regard Europe as a diverse set of national systems of innovation. Firms innovation performance 'depends on numerous and often country-specific institutional, infrastructural and cultural conditions regarding relationships among the science, education and business sectors, conflict resolutions, accounting practices, corporate governance structure, labour relations etc.' (OECD 1999: 21-22). The notion of a 'national system' rests in particular on the assumption that technology continues to have a large element of tacit knowledge that is costly to acquire, and that nations has a large degree of physical, cultural, political and linguistic nearness and sameness that lessen the transfer of tacit knowledge from person to person and from organisation to organisation (Cooke and Morgan 1998).

To be more precise, a specific national innovation system consists of a) a production structure, i.e. a set of customers, competitors and suppliers constituting a specific national industrial cluster or branch of industry, b) knowledge creating organisations, as universities, colleges, R&D institutes that hold important knowledge of relevance for firms' innovation activity, c) knowledge diffusing organisation, as the education system, private consultants and technology centres, d) finance institutions, as the public support system, banks and venture capital, and e) public authorities. The Norwegian petroleum industry has some distinct characteristics concerning these five elements that define a mainly national innovation system.

First, a national petroleum cluster, consisting of oil companies and a lot of different suppliers, has grown up. Second, a particular technology with its related knowledge organisations has been developed in connection with the petroleum industry on the Norwegian continental shelf. This shelf, with its ocean depths and surface powers (wind, waves, and partly ice), is an extremely demanding area from which to extract oil and gas. Even though Norway became a petroleum producer only 30 years ago, much of the petroleum technology developed until then was unsuitable to the extreme natural conditions on the Norwegian shelf. This situation, together with an aim to build a specific Norwegian competence and industry, lead to a particular national demand for new technological solutions that stimulated the innovation

capacity of the Norwegian oil and gas industry. For example, the Aker H3 rig, the Doris concrete platform, the Submerged Turret Loading system (STL) and new positioning systems have all been very important Norwegian innovations triggered by the demand situation in the North Sea (Braadland 1998). Third, the development of the Norwegian petroleum industry is greatly stimulated and influenced by governmental laws, regulations and concession rules. Examples are the establishment of a large state owned oil company (Staoil), regulations to favour Norwegian oil companies, and concession rules and technology agreements to stimulate technology diffusion to Norwegian firms and research institutes.

7.1. User-producer interaction, oil companies – engineering firms

The prime motor in the Norwegian petroleum sector is the 27 oil companies that have different shares in a varying number of oil and gas fields (Figure 8). Haraldsen (1997) conceptualises the Norwegian petroleum sector as a development block which has given rise to a cumulative technological dynamic that has increased the competitiveness of firms belonging to the block. Oil companies are the prime motor or active units in this development block since they are end firms that demand new technological and organisational solutions from their suppliers. All companies in the production system is more or less dependent on the market and price on petroleum products. The oil companies and their suppliers and subcontractors are linked technologically and organisationally in the exploration and development of field and the production of petroleum.

The oil companies and the large engineering firms performing EPC and EPCI contracts have a close co-operation from the very beginning of a new oil and gas development project. The oil companies used to have a lot of their own employees in the engineering companies to follow up projects. The number of people was reduced by the introduction of EPC and EPCI contracts. However, milestones are defined with reports to the customers.

The oil companies have their preferences for specific technology and solutions in new field development. However, ideas for new products and solutions comes mainly from within the off-shore engineering companies, based on experience based knowledge in these companies, and embedded in personal know-how and organisational routines⁷⁷. Innovations often occur stepwise to constantly better existing solutions, but also sometimes as radical new solutions. However, oil companies as potential customers are involved in product development as early as possible. Thus, concrete development projects generally include oil companies, the engineering firm and R&D organisations.

The customers' motivation for taking part in innovation projects run by engineering firms is to achieve cheaper and more effective petroleum installations, that is necessary to develop the more marginal petroleum fields left on the Norwegian shelf and to raise the profit on existing and new fields. In particular, the Norwegian oil company Saga played an important role in co-financing innovation projects and stimulating innovation activity. For example, Saga was a motive power in the

⁷⁷ This is confirmed by interviews both in Kværner Oil & Gas, Aker Maritime Oslo and ABB Offshore Technology.

development of Tension Legs Platforms produced by Aker Maritime, and the company was the world's first customer of a subsea installation.

Box 1: Example of new products

Recent product development includes production ships also performing drilling, i.e. a FPDSO (floating, production vessel with drilling, storage and offloading) concepts developed by Kværner Oil & Gas. This company is also developing a Mini TLP (tension leg platform) with dry well heads, as well as environmental technology to reduce CO₂ and drilling mud. ABB Offshore Systems and Corporate Research have recently developed the first subsea processing construction in the world (Troll Pilot). This company is also involved in further development of 'subsea products', as a robot connecting pipe lines to subsea installations, and a composite raiser, i.e. a pipeline from ships to subsea installations produced by composite materials. Aker Maritime (the Aker Engineering unit) has also been first on the market with new concepts, as TLPs – and eight out of nine of these platforms have been built by Aker Maritime.

For off-shore engineering firms, innovation is necessary to stay in business and make a profit. Low oil prices, small petroleum fields in deep waters and strong environmental regulations demand new technology for many oil fields to be profitably developed. Oil companies expect and require engineering firms to come up with better and cheaper products. Thus, oil companies and engineering firms are involved in a symbiotic relationship. The content and quality of the services provided by engineering companies may to an important degree be defined by the quality of the interactive process of problem solving between these companies and oil companies.

7.2. Interaction between engineering firms and suppliers and subcontractors

The large off-shore engineering firms have a lot of suppliers and subcontractors, both inside the company they belong to and outside of the company. We will distinguish between several types of suppliers and subcontractors. First, one has to notice the distinction between suppliers and subcontractors (Holmes 1986). Suppliers deliver ready-made parts and components that the customers may buy on the market. 'Subcontracting', on the other hand, refers to a situation where the customer firm request another independent enterprise to undertake the work according to specifications or plans provided by the customer. Thus, subcontracting demands an actual contract between the two participating firms setting out the specification for the order.

Accordingly, one may distinguish between two main types of subcontracting, capacity subcontracting and specialisation subcontracting, respectively (op. cit.). In the first case, production of a component is carried out by the subcontractor according to a detailed set of plans and specifications set down by the customer. Usually the customer is able to do the work in house, i.e. the customer farms out overflow work that could normally be done in house except for a current excess of orders relative to their capacity. In specialisation subcontracting the customer and the subcontractor are engaged in different but complementary activity. The subcontractor

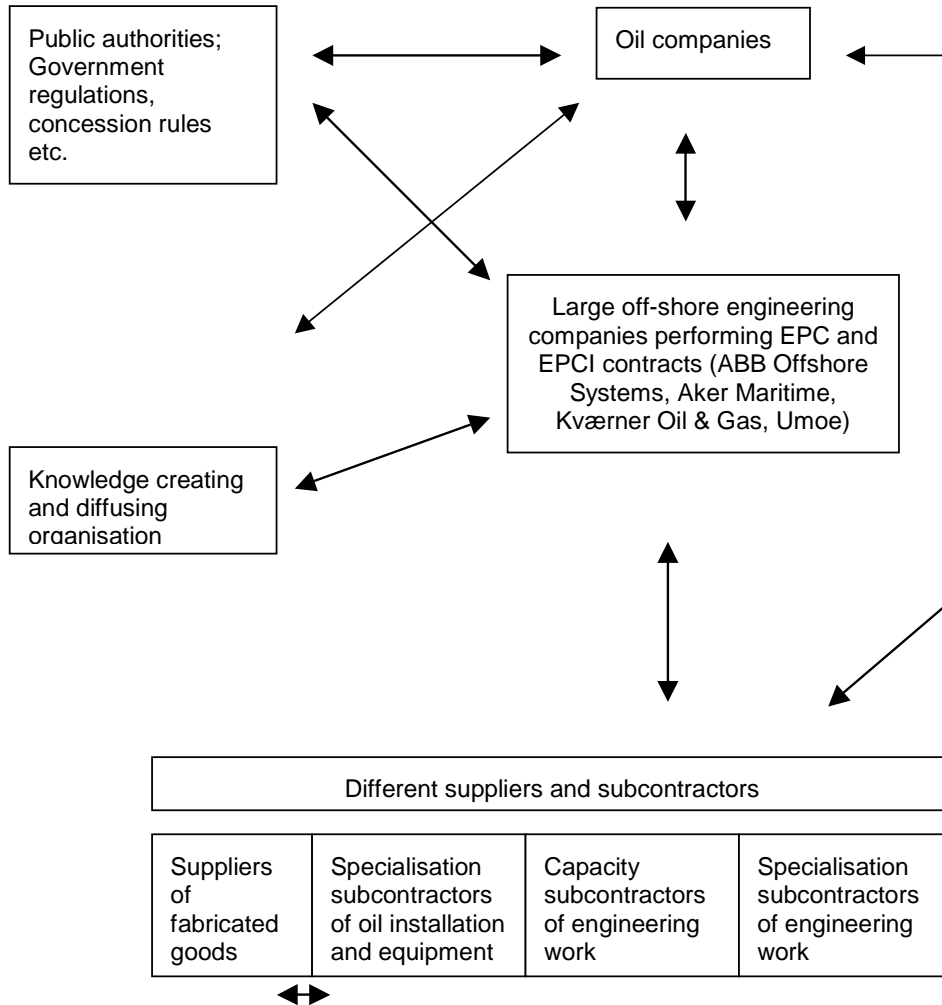
holds know-how that the customer do not have, and the decision how to do the actual work is taken by the subcontractor.

The large off-shore engineering companies have two main types of suppliers and subcontractors, other engineering firms involved in the engineering process and manufacturing firms producing parts of the oil installation, respectively. Subcontracting usually refers to manufacturing production of a component, part etc. according to specifications. However, we will use the two concepts of capacity and specialisation subcontractors also to distinguish between two types of engineering firms. Specialisation subcontracting may denote firms and consultants with specialised competence that the large firms do not have themselves. The large engineering firms hire many consultants on engineering projects and development projects. Kværner Oil & Gas used to have around 1.000 consultants, mainly graduate engineers specialised in certain fields. Aker Maritime Oslo buys in specialised competence in drilling and seismics, mainly from small local firms with 1-15 employees. Several of these firms are established and run by former engineers at Aker. The large firms also hire extra engineering capacity in busy periods. Aker Maritime, for example, use recruiting companies as Manpower for this task. Such kind of capacity subcontracting is probably more easily managed in a large labour market as the Oslo area

The large engineering firms in the Oslo area perform development, design and engineering of petroleum installations, and project management and purchase. However, EPCI contracts also include production and installation, that demands a lot of suppliers and subcontractors. However, Kværner Oil & Gas and Aker Maritime Oslo are parts of larger companies including yards and several producers of equipment. These firms are in a way the engineering departments of larger companies, and one of their task is to supply the companies' yards and other production plant with work. ABB Offshore Systems does not have their own yards that produce installations. However, ABB has two main subcontractors in Norway; Hermea in Tønsberg that produces platforms and Nymo in Grimstad that produces subsea installations.

The yards and some other producers of equipment are a kind of specialisation subcontractors having a close co-operation with the off-shore engineering companies. The yards, such as Kværner Rosenborg in Stavanger, Aker Stord, Hermea and Nymo, are included in projecting at an early stage. Engineers employed at the yards move to Oslo to work together with the engineering firm on design and planning. When production starts some engineers move the opposite way, from the engineering firm in Oslo to the yards to follow up the production work.

Figure 8: A simplified presentation of the Norwegian innovation system in petroleum production



In addition to close contact with the yards, the engineering companies have framework agreements with a number of other key firms. Aker Maritime, for instance, have framework agreements with around 15 firms. Among them are Simrad Kongsberg and Kongsberg Offshore Systems. The rest are mainly software producers in the Oslo area. ABB Offshore Systems buys mostly from other firms within the ABB company around the world, as ABB wants to control the key technology that gives most value added. The main subcontractors are included in the project work at an early stage to fit their products into the total project. Framework agreements result in the use of the same products in several projects, that may lead to standardisation and lower costs instead of tailor-making product in every project. A lot of other firms take part in the production of oil installations as suppliers, in the way we have

defined this term. The suppliers deliver standard goods and services and do mainly compete on price.

The way of organising design, engineering and production of petroleum installations described above also reflects a kind of spatial division of labour in the Norwegian petroleum industry. Much of product development, design, engineering and project management are carried out in the Oslo area, while production work mainly takes place along the southern and western coastline. In this way engineering firms in the Oslo area perform a particular task in feeding works to firms in other parts of the country. Although engineering firms and production plants co-operate closely on engineering, the competence in new technology and product development in the engineering firms (together with the size of the market) to a large extent decide the amount of work carried to the yards and other production units..

7.3. Interaction between engineering companies and the knowledge infrastructure

The petroleum sector also draws knowledge from a broad range of R&D organisations. A mapping performed by the STEP Group identifies more than 50 R&D organisations in Norway holding competence and research in relevant technical fields (cf. Appendix). The mapping points to a complex and science-based knowledge base behind the Norwegian petroleum industry. Research results will certainly flow into the industry in several ways, as co-operation on innovation projects and recruitment of personnel.

Most of knowledge organisations are located in the four largest cities in Norway; only seven institutions are located outside of Oslo, Bergen, Trondheim and Stavanger. The strongest R&D milieu is found in Trondheim with approximately 20 institutions and university departments, where IKU (Continental shelf and petroleum technology research) and SINTEF are the most used institutions in research projects co-financed by the Norwegian research council. Oslo is the main site for geology, physics and chemistry research of relevance for the petroleum sector; research found in university departments and private R&D-institutes.

Box 2: Science and Technology Infrastructure Institutions relevant for the petroleum sector and located in the Oslo area

- University of Oslo, several departments
- SINTEF, several departments
- Norwegian Water Technology Centre
- Norwegian Meteorological Institute
- Det Norske Veritas Research AS
- Institute for Energy Technique
- The Norwegian Institute for Masonry and Concrete Research
- Norwegian Geotechnical Institute
- Norwegian Institute for Water Research
- The Norwegian Seismic Array
- Norwegian Polar Institute

Innovation activity in the off-shore engineering firms takes mainly place inside the firms, but always in collaboration with oil companies and often also including some R&D organisations. The large engineering firms, as Kvaerner Oil & Gas, Aker Maritime Oslo and ABB Offshore Systems, have their own R&D projects. The firms earmark internal means for the development of new products, and the product development is normally co-financed by oil companies and the Norwegian Research Council. The education level in the petroleum sector, for example measured as relative share of PhDs and higher university/college education, is clearly higher than the average of other industries. The petroleum sector is also the most R&D intensive sector in Norway, both measured by R&D expenditures per employees and in absolute sense.

Aker Maritime Oslo and Kvaerner Oil & Gas, however, have low R&D budgets in 1999 due to weak working results in 1998. Nevertheless, these firms normally perform R&D to develop new products. The accomplishment of R&D projects applies to ABB Offshore System even in 1999. ABB has its own research department, Corporate Research, performing applied research. Corporate Research has a 40 person unit at Asker, with its own research laboratory to test models, and collaborating on development projects with ABB Offshore Systems. Units inside ABB may apply for means from Corporate Research. Then a specific project is established, co-financed by Corporate Research, an other ABB unit and also often including customers. The last years ABB Offshore Systems has succeeded in designing research projects, in co-financing projects with Corporate research, and in introducing new products to the market fast.

The main object of research activities in the off-shore engineering companies is to be the first one with a completely new product or solution, i.e. a technological breakthrough that may open a big market and gain a large profit for the company. Both old and recent examples on such radical innovations exist. The idea for new products mainly comes from the engineering companies themselves and from discussions with oil companies.

8. Policy discussion

The concluding policy discussion takes as its departure two main current challenges facing the off-shore engineering cluster in the Oslo area. The first is a decreasing development activity on the Norwegian continental shelf, resulting in a diminishing demand for new petroleum installations, in particular for large installations, as the remaining fields are generally smaller. The demand is directed towards smaller and more cost efficient installations, requiring fewer engineers to develop and in particular fewer workers to build. Some large engineering firms downsize and loose highly qualified employees, especially among the youngest ones. This may damage the competitiveness of these firms in the long run, however, the current lay-off of oil engineers in the Oslo area may also bring about some revitalisation of other parts of the regional economy. The second challenge is related more directly to the off-shore engineering cluster in the Oslo area. With decreasing activity, probably a harder fight between regions to become the centre of the Norwegian petroleum industry will occur in the future. The Oslo area has been loosing in importance measured by share of employees for several years, also in engineering activities.

What are the answers on these main challenges? The first challenge relates to the national level and demands first of all initiatives from national authorities. One have to keep in mind that the Norwegian petroleum industry and innovation system to a large extent have been created by means of governmental initiatives, for example concession rules and technology agreements in order to build up competence and a competitive national industry. New initiatives could be required in a situation of seemingly permanent lower development activities.

We will briefly point to three kinds of answers and possible governmental initiatives related to the first main challenge. First, increased innovation activity may be one answer. Off-shore engineering companies, yards and other manufacturing firms try to develop effective and cheap solutions suited to the physical and legislative conditions on the Norwegian shelf, so that oil companies may choose to develop oil fields on the Norwegian shelf rather than elsewhere. Thus, successful product development may raise the development activities and the recourse exploitation on the Norwegian shelf.

Public co-financing of R&D-projects may be required in a situation where oil companies and engineering firms seem to have less internal capital to invest in research and development. The recently started research programme DEMO 2000 co-finances product development, and seems to result in increased innovation activity in engineering firms. Thus, DEMO 2000 supports innovation projects in both ABB Offshore Systems, Aker Maritime and Kværner Oil & Gas. The public support in the programme amounts to 100 mill NOK, oil companies contribute with another 100 mill NOK, while engineering firms, subcontractors etc. contribute with the same amount of money. Programmes like DEMO 2000 are also important in the effort to renew and restructure Norwegian industry through the development of more R&D-intensive products.

Another answer may be to stimulate the petroleum activity on the Norwegian shelf also by other means than increased innovation activity, for example more attractive conditions for oil companies. A third answer is increasing internationalisation of activity to compensate – at least partly – for the decreasing activity on the Norwegian shelf. The large engineering companies do establish themselves on international

markets. For instance, Aker Maritime has bought up one engineering company and two yards in USA, and a similar strategy has been followed in the UK. Thus, Aker Maritime now has between 2000 and 3000 employees in both USA and the UK, and technology has been exported from Norway to Aker's companies in these two countries. Kværner Oil & Gas has activity both in the Caspian sea, western Africa, the Gulf of Mexico, and in deep waters outside of Brazil. Then, the firm partly follows existing customers to new areas, as well as meeting new oil companies. The publicly owned Norwegian oil companies Statoil and Hydro (partly publicly owned) could have a special responsibility in drawing Norwegian engineering firms and subcontractors on to the international market, by letting Norwegian firms prove their competitiveness on development projects on foreign markets.

The other main challenge refers to a decreasing national share of jobs in off-shore engineering in the Oslo area. It seems that other regions, like Stavanger and Kristiansand, work hard to maintain their existing firms and attract firms from other areas by means of local policy instruments as attractive building sites for houses and offices⁷⁸. This may require more offensive initiatives also by regional authorities in the Oslo area if one wants the area to keep up its position as the centre of off-shore engineering in Norway.

More offensive initiatives may comprise a strengthening of the regional innovation system, as well as attempts to make the best out of the current lay-off of engineers.

Principally, a strengthening of the regional innovation system may take place by two main means; 1) to stimulate the establishment of new actors in the system, and 2) strengthen innovation collaboration between the actors. New actors include some foreign oil companies that establish themselves in the Oslo area (close to the Ministry of oil and energy) in order to fight for contracts in the next concession round. It could be important to maintain these in the Oslo area. More oil companies may stimulate innovation collaboration between these firms and local engineering firms, and increasing the attractiveness of the Oslo area as a location for off-shore engineering firms.

The weakest part of the regional innovation system around off-shore engineering in the Oslo area seems to be relatively little innovation co-operation between engineering firms and R&D milieus. Oil companies and subcontractors and suppliers are much more important sources of innovation than R&D milieus (cf. Table 7). This is a general situation for most of Norwegian industry, as revealed by the Community innovation survey. However, technical engineering firms in the Oslo area have less R&D costs than corresponding firms in the rest of Norway, and the large engineering firms have little co-operation with R&D-institutions in Oslo-Akershus. Thus, there could be a potential for enhanced contact and innovation collaboration between off-shore engineering firms and R&D institutions in this area.

The current lay-off of oil engineers may also be an 'opportunity' for revitalising other parts of the regional industry. This may take place in at least two ways. First, laid-off engineers could start their own business, and public policy instruments may stimulate them to do so. The FORNY concept could be a model for such a policy

⁷⁸ At least, this is how the situation is interpreted by some firm leaders, as Tor Olav Kristoffersen and Per Flugstad in Aker Maritime. Their view is supported by a larger growth in the number of off-shore engineering jobs in these areas than in Oslo-Akershus the last years(cf. Figure 3).

instrument, both stimulating laid-off engineers to consider start-up as a realistic alternative, as well as supporting those who decide to start their own business with advice, practical help and perhaps capital.

The other main possibility for revitalisation is to help in particular small and medium sized enterprises (SMEs) in recruiting laid-off engineers. Lack of competence and little time left for entrepreneurs and engineers to engage in long term innovation projects are generally seen as important innovation barriers in SMEs. Thus, to help local SMEs employ experienced engineers could stimulate innovation capability and activity in the firms. The policy instrument SME competence may represent a relevant model for such an initiative. This instrument support the recruitment of new candidates to work one year with a specific innovation project in an SME.

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Appendix: Key activities, techniques, knowledge bases and research institutions in different phases of the Norwegian offshore sector⁷⁹

<i>Field exploration phase</i>			
Key activity	Technique	Knowledge base	Research institution
Collecting geological data	Operating marine vessels	Navigation	NTNU-TC
	Seismic acquisition	Seismology	SINTEF TI, UiO-G, UiB-ISEP, NTNU-DoT, NORSAR, Statoil
	Drilling	Engineering / material technology	SINTEF Ch, SINTEF CEE, SINTEF MT, SINTEF U, Molab, UiO-Ch, UiB-P, HiS-MMT, NORUT t, MBS, MARINTEK, NTNU-GE, RF, Statoil
		Physics	SINTEF CEE, SINTEF MT, UiO-G, UiO-Gp, UiB-ISEP
	Geology	UiO-G, UiB-G, IKU, HiS-DPT, HiS-MMT, IKU, NGU, NP, RF, Statoil	
Analyzing geological data	Seismic interpretation	Seismology	SINTEF TI, UiO-G, UiB-P, UiB-ISEP, NORSAR, Statoil
	Geological interpretation	Geology	UiO-G, UiB-G, Statoil, IKU, HiS-DPT, MMT, IKU, NGU, NP, RF
		Geophysics	UiO-G, UiO-Gp, UiB-G, IKU, NTNU-P, NGU, NP, Statoil
		Geochemistry	UiO-G, NGU
<i>Field development phase</i>			
Key activity	Technique	Knowledge base	Research institution
Engineering and manufacturing the installations	CAE/CAD/CAM (cybernetics)	Industrial instrumentation (cybernetics)	UiB-P, HiBu-ETC, SINTEF AM, SINTEF TI, MPP, CMR, IFE, MBS, SINTEF EC, NTNU-DTC, HiBu-ETC, HiS-EC
		Engineering/ material technology	SINTEF Ch, SINTEF CEE, SINTEF MT, SINTEF U, Molab, UiO-Ch, UiB-P, HiS-MMT, NORUT t, MBS, MARINTEK, NTNU-GE, RF, NORSAR, NAT, HiM
		Physics	SINTEF CEE, SINTEF MT, UiO-G, UiO-Gp, UiB-ISEP
		Geology	UiO-G, Statoil, UiB-G, IKU, DPT, HiS-MMT, NGU, NP, RF, SINTEF AM, NGI
		Climatology	SINTEF AM, SINTEF E, MARINTEK, UiO-Gp, NTNU-MH, NORUT, IT, DNMI
		Mechanics	SINTEF Ch, SINTEF AM, UiO-P, DPT, RF, HiM
		Machinery	MARINTEK, NTNU-DTC, HiS-MMT
	Construction, mechanics, electronics, electricity	Engineering/ material technology	SINTEF Ch, SINTEF CEE, SINTEF MT, SINTEF U, Molab, UiO-Ch, UiB-P, HiS-MMT, NORUT t, MBS, MARINTEK, NTNU-GE, RF, NORSAR, NAT, HiM
		Geometry	SINTEF AM
		Subsea technology	NTNU-MPP, HiS-MMT, FFI, MARINTEK, Nutec, Statoil
		Optimisation	SINTEF AM
	Machine techniques	Mechanical engineering	SINTEF Ch, SINTEF AM, UiO-P, HiS-DPT, RF
		Electronics	SINTEF EC, UiB-P
Subsea technology		NTNU-MPP, Statoil, HiS-MMT, FFI, MARINTEK, DNV, Nutec	
Installation	Mooring	Cybernetics	MARINTEK, DNV
		Geometry	SINTEF AM

⁷⁹ Source: Braadland (1998)

<i>Petroleum production phase</i>				
Key activity	Technique	Knowledge base	Research institution	
Maintenance	Construction, mechanics, electronics, electricity	Engineering/ material technology	SINTEF Ch, SINTEF CEE, SINTEF MT, Statoil, SINTEF U, Molab, UiO-Ch, UiB-P, HiS-MMT, NORUT t, MBS, MARINTEK, NTNU-GE, RF, DNV, NAT, HiM	
		Geometry	SINTEF AM	
		Subsea technology	NTNU-MPP, HiS-MMT, FFI, MARINTEK, Nutec, Statoil	
		Optimisation	SINTEF AM	
	Machine techniques		Mechanic engineering	SINTEF Ch, SINTEF AM, UiO-P, HiS-DPT, RF, HiM
			Electronics	SINTEF EC, UiB-P
			Subsea technology	NTNU-MPP, HiS-MMT, FFI, MARINTEK, Statoil, Nutec
			Cybernetics	SINTEF EC, HiS-DTC, HiBu-ETC, HiS-EC
Surveillance	Monitoring / well logging/ production logging	IT -engineering	SINTEF EC, SINTEF TI, MBS, MARINTEK	
		Computer imaging	SINTEF Ch, SINTEF EC	
		Electronics	SINTEF EC, UiB-P	
		MR	UiB-Ch	
		Optics	SINTEF EC, UiB-P	
		Acoustics	SINTEF Ch, SINTEF TI, UiB-P, NTNU-DoT, CMR, IKU	
		Wave analysis	SINTEF AM, SINTEF CEE, UiO-Gp, UiO-Gp, NTNU-MH	
Well handling, reservoir technology and transportation	Reservoir evaluation	Geology	SINTEF AM, UiO-G, HiS-DPT, HiS-MMT, IKU, NGU, NGL, RF, Statoil	
		Geophysics	SINTEF CEE, SINTEF MT, UiO-G, UiO-Gp, UiB-ISEP, Statoil	
		Geochemistry	UiO-G, NGU, Statoil	
	Gas and water injection		Geochemical engineer.	IKU, RF, IFE, NTNU-DIC, HiS-DPT, AQUA
			Numerical simulation	SINTEF Ch, SINTEF AM, HiS-DPT
	Storage		Engineering/material technology	SINTEF CEE, MBS
	Processing, separation/streaming tech.		Geochemistry	SINTEF Ch, SINTEF AM, UiO-P, HiS-DPT, RF, CMR, IFE, UiB-C, NTNU-DIC, MARINTEK, Statoil
	Transportation / pipelines		Engineering/ material technology	MBS, NAT, DNV, HiM
			Geochemistry	SINTEF E
	Raffining		Geochemistry	SINTEF Ch
Safety and environment	Life and environmental protection	(Varieties)	HiS-DPT, HiS-MS, RF, SINTEF Ch, SINTEF AM, IKU, SINTEF UNIMED, SINTEF E, HSH-DE, CMR, UiO-G, NORUT, NERSC, NIVA, RF, DNV, NORSAR, NAT, Nutec, AQUA, Statoil	

Abbreviations:

Universities and colleges

HSH-DE = Department of Engineering, College of Stord/Haugesund
HiM = College of Molde/Møre Research (Møre and Romsdal Research Foundation)
HiS-DPT = Department of Petroleum Technology, College of Stavanger
HiS-EC = Department of Electronics and Computing, College of Stavanger
HiBu-ETC = Department of Electronics and Technical Cybernetics, College of Buskerud, Kongsberg
HiS-MMT = Dep. of Machinery and Material Tech., College of Stavanger
HiS-MS = Department of Mathematics and Science, College of Stavanger,
NTNU = The Norwegian University of Science and Technology, Trondheim
NTNU-DIC = Department of Industrial Chemistry, NTNU, Trondheim
NTNU-DoT = Department of Telematics, NTNU, Trondheim
NTNU-GE = Department of Geotechnical Engineering, NTNU, Trondheim
NTNU-MH = Department of Marine Hydrodynamics, NTNU, Trondheim
NTNU-MPP = Department of Marine Project Planning, NTNU, Trondheim
NTNU-P = Department of Physics, NTNU, Trondheim
NTNU-TC = Department of Technical Cybernetics, NTNU, Trondheim
UiB-Ch = Department of Chemistry, University of Bergen,
UiB-G = Department of Geology, University of Bergen,
UiB-Gp = Department of Geophysics, University of Bergen,
UiB-ISEP = Department of Solid Earth Physics, University of Bergen,
UiB-P = Department of Physics, University of Bergen
UiO-Ch = Department of Chemistry, University of Oslo
UiO-G = Department of Geology, University of Oslo,
UiO-Gp = Department of Geophysics, University of Oslo,
UiO-P = Department of Physics, University of Oslo

Institutes and private institutions

AQUA = AQUATEAM - Norwegian Water Technology Centre, Oslo
CMR = Christian Michelsens Research AS, Bergen
DNMI = Norwegian Meteorological Institute, Oslo
DNV = Det Norske Veritas Research AS
FFI = Norwegian Defence Research Establishment, Horten
IFE = Institute for Energy Techniques, Oslo
IKU = Continental Shelf and Petroleum Technology Research, Trondheim
MARINTEK = Norwegian Marine Technical Research Institute, Trondheim
MBS = The Norwegian Institute for Masonry and Concrete Research, Oslo
Molab = SINTEF Molab, Mo
NAT = Norwegian Applied Technology
NERSC = Nansen Environmental and Remote Sensing Centre, Bergen
NGI = Norwegian Geotechnical Institute, Oslo
NGU = Geological Survey of Norway, Trondheim

NIVA = Norwegian Institute for Water Research, Oslo

NORSAR = The Norwegian Seismic Array, Oslo

NORUT = NORUT IT, Tromsø

NORUT t = NORUT technology, Narvik

NP = Norwegian Polar Institute, Oslo

Nutec = Norwegian Underwater Technology Centre, Bergen

RF = Rogaland Research, Stavanger

SINTEF = The Foundation for Scientific and Industrial Research

SINTEF AM = SINTEF Applied Mathematics, Trondheim/Oslo

SINTEF CEE = SINTEF Civil and Environmental Engineering, Trondheim

SINTEF Ch = SINTEF Chemistry, Trondheim /Oslo

SINTEF E = SINTEF Energy, Trondheim

SINTEF EC = SINTEF Electronics and Cybernetics, Trondheim/Oslo

SINTEF MT = SINTEF Materials Technology, Trondheim /Oslo

SINTEF TI = SINTEF Telecom and Informatics, Trondheim/Oslo

SINTEF U= UNIMED, Trondheim/Oslo

Statoil = Statoil Norway, Trondheim

Appendix: Description of statistical data sources

The Norwegian Employment Register

Norwegian Employment Register is a dataset with information about employees and companies in Norway. The set covers all companies and employees in the Oslo region in the period 1986-1996. The main variables in the set is in which company the employee works, the specific industry of the company (5-digit NACE code), the company size (in number of employees), the company community and county, employee community and county and his or her highest education. The gathering of data is co-ordinated by Statistics Norway (SSB).

The CIS database

The CIS database contains information about innovation, R&D and economic performance on about 3.000 Norwegian companies, of which appr. 800 is located in the Oslo region. The set covers all sectors and company sizes, and was collected in 1997. More specifically, the dataset provides information on company level about innovation expenditures, changes in products, process or organisation, profits from innovation, innovation sources, R&D expenditures etc. The data is collected simultaneously in all EU and EAA (EØS) countries, in Norway by National Bureau of Statistics.

National Manufacturing Statistics

Contain main figures about manufacturing industries, as found in publications from National Bureau of Statistics. The publications contain information about turnover, value added, employment, industrial structure and company size for all companies with more than 9 employees in the Oslo region. The statistics are collected yearly.

Norwegian Research and Development Database

Statistics on R&D in Norwegian enterprises, gathered biannually by National Bureau of Statistics. Data cover activities for all firms with 50+ employees (in 1995: 2.557 companies) and randomly picked 2.820 companies with less than 50 employees.

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STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitik og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.